



HAZARDOUS  
SITE CONTROL  
DIVISION

**Remedial  
Planning  
Field  
Investigation  
Team  
(REM FIT)  
ZONE II**

CONTRACT NO.  
68-01-6692

**CHEMURHILL**  
Ecology &  
Environment

**FINAL**

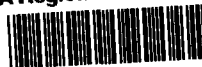
**FEASIBILITY STUDY REPORT**

**CHARLEVOIX SITE  
CHARLEVOIX, MICHIGAN**

**W65253.A0**

**June 10, 1985**

**EPA Region 5 Records Ctr.**



**209252**

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GLT441/120

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## Chapter 1 EXECUTIVE SUMMARY

The goal of this Feasibility Study (FS) is to select and evaluate remedial action alternatives for protecting the public health, welfare, and environment from contaminated groundwater in the aquifer below Charlevoix, Michigan. The methods and criteria are those outlined by the Nation Oil and Hazardous Substances Contingency Plan, 40 CFR 300.68.

The present water supply system is contaminated with trichloroethylene (TCE) and the aquifer contains TCE and perchloroethylene (PCE). Concentrations of TCE and PCE exceeding the levels currently found in the city well have been found upgradient of the city well. Data gathered during early 1984 by the remedial investigation team indicated that increases in the present concentrations of the contaminants could be expected to occur in the near future. A focused feasibility study was conducted during March and April of 1984 to evaluate interim measures that could be implemented to provide clean water to the residents of Charlevoix, Michigan. The Focused Feasibility Study recommended that a lake water intake and treatment plant be constructed to provide Charlevoix residents with a new safe water supply. This FS makes the assumption that the new water supply will be constructed.

The endangerment assessment establishes that if no future remedial actions are taken to remove contaminants from the groundwater or if no land use restrictions or deed restrictions are implemented there will still be a substantial health risk ( $4 \times 10^{-4}$ ) exceeding the one in 1,000,000 cancer risk level for a population exposed to the concentrations of TCE and PCE found in the aquifer over a standard lifetime. The probability of someone installing a well in the contaminated plume area when city water is available cannot be predicted though it could occur if no restrictions are in place.

The options to reduce risk to human health and environmental effects are:

- o Monitor the contaminant plumes and institute land use and deed restrictions making potable use of groundwater illegal.
- o Remove the contaminated groundwater and discharge it untreated to Lake Michigan.
- o Remove and treat the contaminated groundwater to remove the contaminants.

The proposed alternatives which would limit access or exposure to the contaminated groundwater are evaluated based on their ability to effectively address the following:

- o Public health evaluation--endangerment to human health via exposure through ingestion of water, dermal absorption, inhalation of volatiles, and ingestion of contaminated fish.
- o Environmental assessment--endangerment to biota via exposure to contaminated water.
- o Technical evaluation--evaluation of performance, reliability, implementability, and safety.
- o Institutional issues--compliance with federal, state, and local standards, criteria and guidance. Also evaluated are public involvement and community effects.
- o Cost--capital, operation and maintenance, and present worth costs (assuming 10 percent interest rate).

Pertinent factors considered during this study are:

- o There are two primary contaminant plumes, one of TCE and one of PCE.
- o The regional groundwater flow will move these plumes toward Lake Michigan with eventual mixing and dilution of the contaminants with Lake Michigan water.
- o The rate of movement is different for each plume. It is estimated to take between 5 and 8 years for groundwater to move from the plume areas to Lake Michigan. Because of uncertainties in evaluating sorption/desorption effects, the range of time estimated to be required to flush the contaminants to Lake Michigan by natural groundwater flow varies from 30 years to as long as 200 years. Based on aquifer and chemical properties within this range, a most probable time to clean up of 50 years is estimated.
- o Clean up of the aquifer by pumping out the contaminated water can accelerate the contaminant removal process, narrowing the estimated range of time to clean up to between 10 and 50 years. Based on parameters within this range, a most probable time to clean up of 30 years is estimated.
- o Purging wells would require drawdowns of 25 feet and combined pumping rates of 750 gpm to capture

the contaminant plumes. Treatment facilities must be capable of treating at least that amount.

- o The area having a concentration of TCE greater than 100 ug/L and the area having a concentration of PCE greater than 25 ug/L is relatively well defined, but it is surrounded by a large, ill-defined area having a level of contamination greater than 2.8 ug/L for TCE and 0.88 ug/L for PCE, the  $10^{-6}$  drinking water cancer risk level.
- o Cleanup down to 10 ppb for TCE and PCE is possible within the estimated periods for both contaminants, but cleanup from 10 ppb to below the  $10^{-6}$  cancer risk level is very difficult to predict due to the seemingly ubiquitous occurrence of low levels of TCE throughout the study area.

The primary alternatives identified for treating the contaminated groundwater are carbon adsorption and air stripping. The cleanup alternatives are essentially equivalent in all criteria on a 30-year evaluation basis except for cost. Air stripping will cost approximately \$350,000 more than carbon adsorption.

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## **Chapter 2 INTRODUCTION**

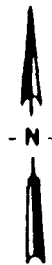
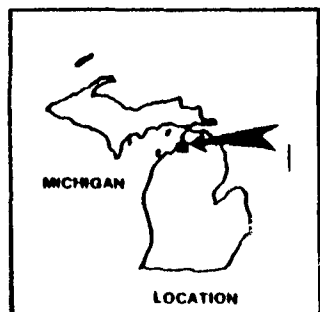
This feasibility study (FS) addresses remedial action alternatives for protecting the public health, welfare, and environment from contaminated groundwater underlying the city of Charlevoix, Michigan. An Initial Remedial Measure (IRM) to construct a Lake Michigan water intake structure and treatment plant to provide uncontaminated drinking water to city residents is currently planned to be completed by mid-year 1986. This FS assumes the new water supply system will be constructed.

The FS is prepared in partial satisfaction of Contract No. 68-01-6692, Work Assignment No. 46.5L53.0, and the Final Work Plan Tasks 1 through 4 for the Charlevoix site in Charlevoix, Michigan.

### **SITE BACKGROUND INFORMATION**

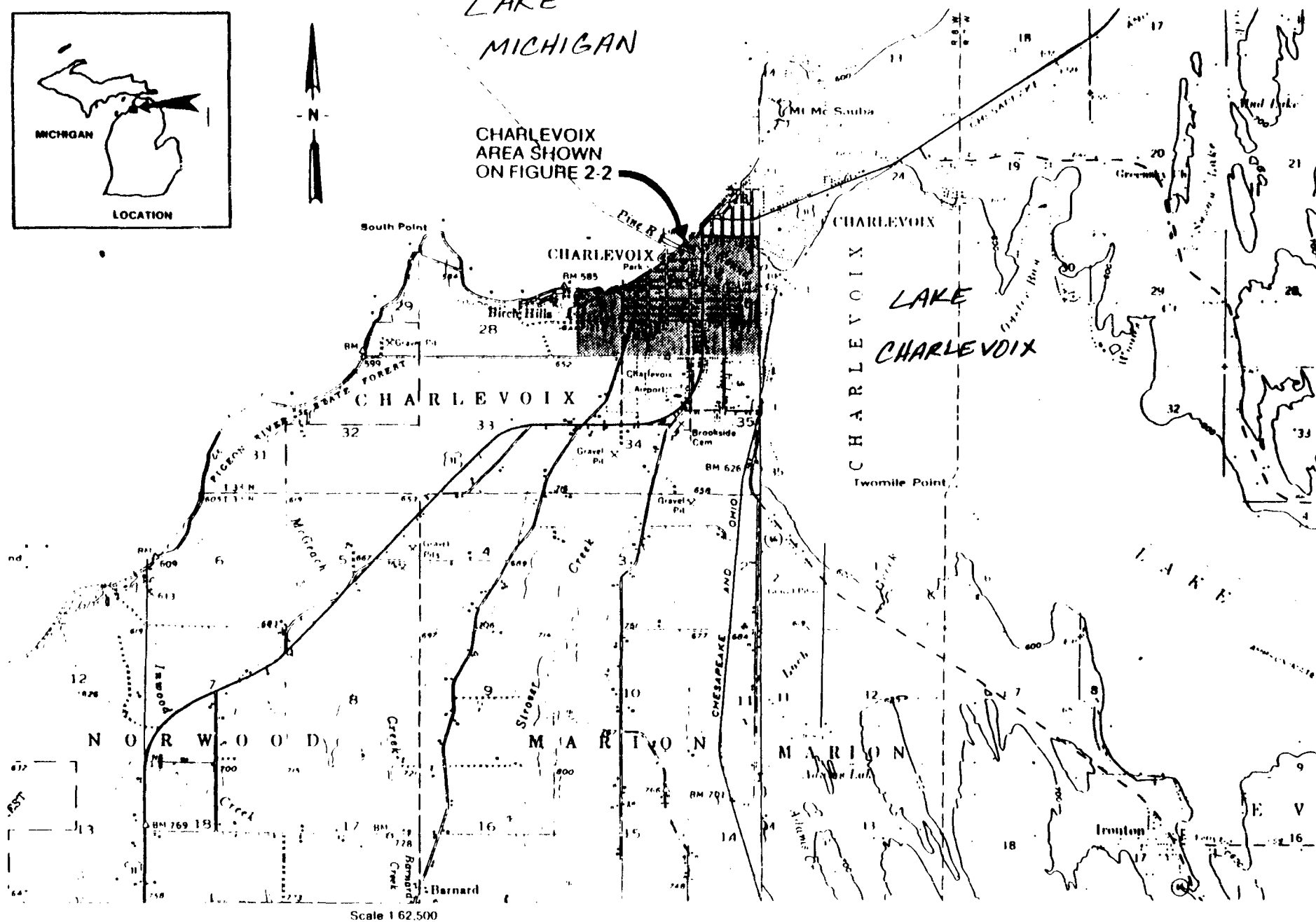
The City of Charlevoix is located in the northwestern part of the Lower Peninsula of Michigan on the shore of Lake Michigan (Figure 2-1). The Charlevoix municipal well supplies the year-round population of 3,500 residents and the summer influx of an additional 1,500 part-time residents with potable water. The well consists of a caisson (a shallow, large-diameter well) and flume collection system buried in beach deposits 80 feet from the Lake Michigan shoreline (Figure 2-2). Two 225-foot long flumes extend from the caisson in both directions parallel to the lake shore, receiving water from the groundwater system and from infiltration of Lake Michigan water through the beach sands.

The groundwater comes from a Wisconsin age glacial drift aquifer. The glacial deposits are dominated by ground moraine, with less extensive sandy lake deposits located along the margins of Lake Michigan and Lake Charlevoix in western Charlevoix County. The soil developed from the glacial deposits is primarily well-drained, loamy sand belonging to the East Lake Series (SCS, 1974). In Charlevoix Township, there are generally 50 to 100 feet of the sandy glacial deposits overlying limestone and shale formations of the Traverse City Group. In the vicinity of the collection system, the aquifer consists of brown sands with varying amounts of silt and gravel. The collection system is located in a discharge area for the glacial drift aquifer. Static water level data from the monitoring wells near the municipal well indicate that the primary groundwater flow direction is toward Lake Michigan and Round Lake (Figure 2-3).



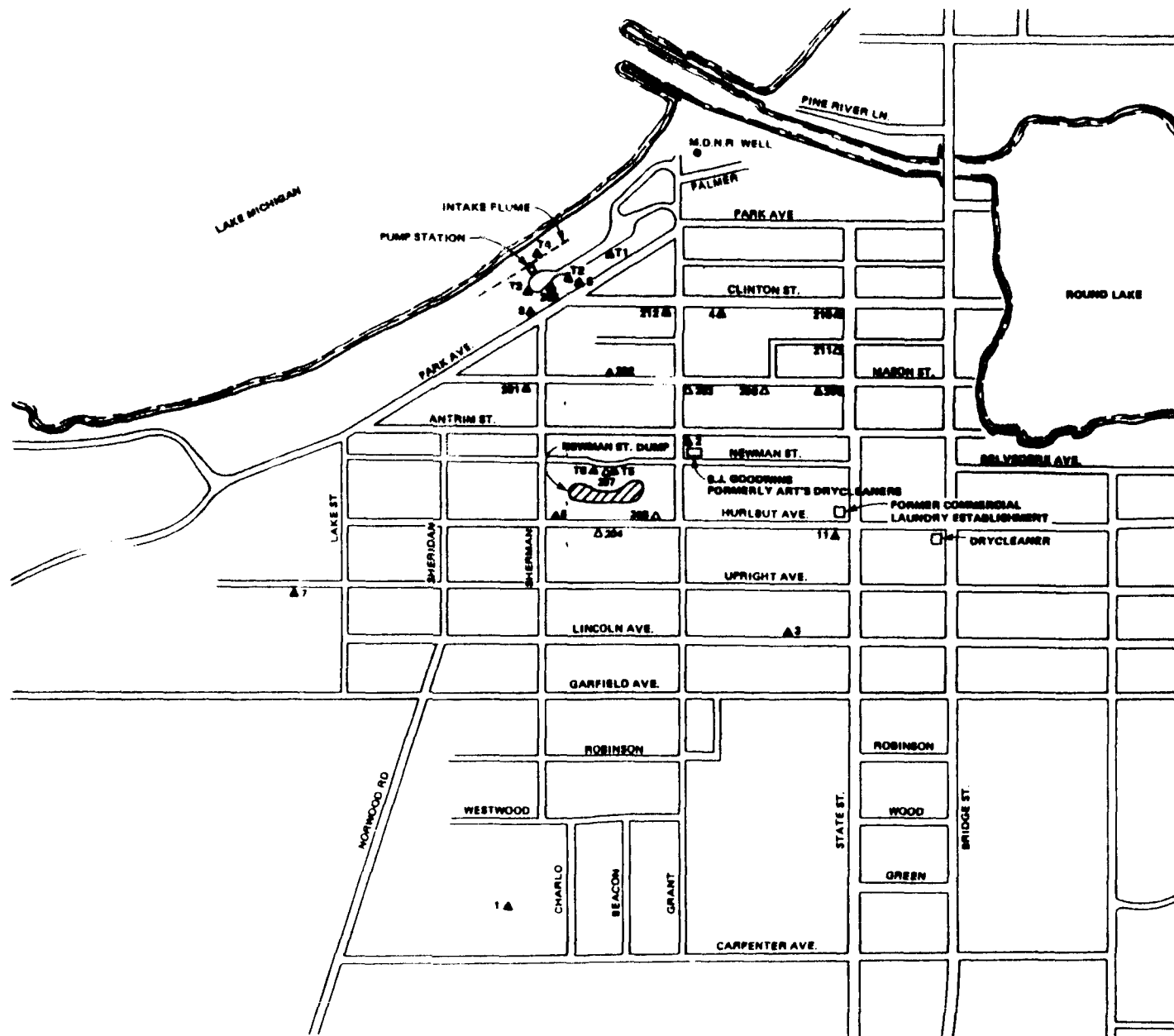
LAKE  
MICHIGAN

CHARLEVOIX  
AREA SHOWN  
ON FIGURE 2-2



Source: USGS 15 MINUTE QUADRANGE:  
CHARLEVOIX AND BAYSHORE

**FIGURE 2-1**  
**VICINITY MAP**  
CHARLEVOIX SITE

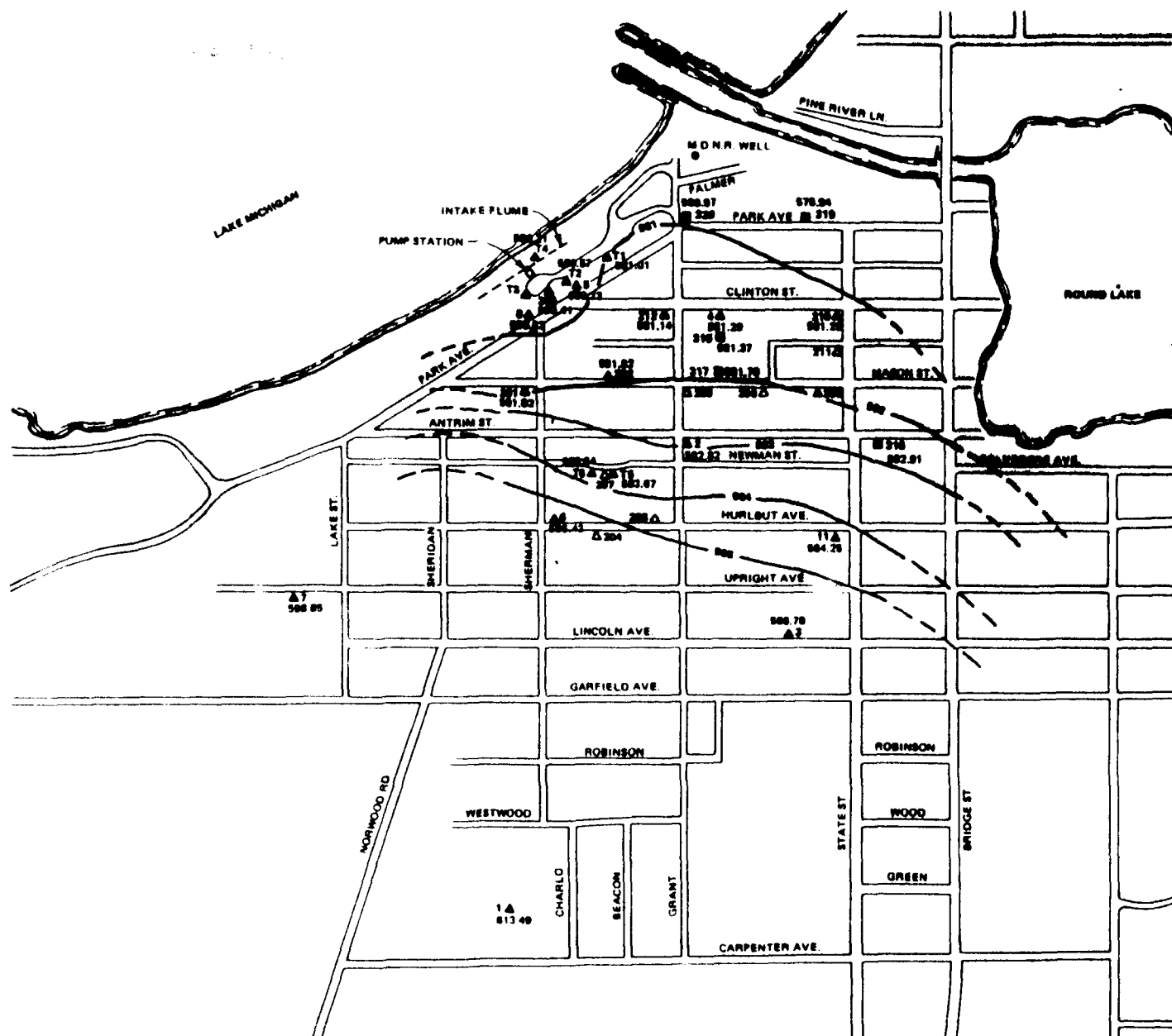


LEGEND

- ▲ EXISTING MONITORING WELL - INSTALLED BEFORE JANUARY 1984
- △ BORING LOCATION - DECEMBER 1983



FIGURE 2-2  
SITE MAP  
CHARLEVOIX SITE



**FIGURE 2-3**  
EXISTING MONITORING WELL LOCATIONS  
AND GROUNDWATER CONTOUR MAP  
JULY/AUGUST 1984  
CHARLEVOIX, MICHIGAN

In September 1981, the Michigan Department of Public Health (MDPH) detected trichloroethylene (TCE) ranging in concentrations from 13 ug/L to 30 ug/L in tap water from the Charlevoix water supply system. A monitoring program was begun and continued to detect gradually rising levels of TCE at the well. In December 1982, concentrations of TCE exceeded 100 ug/L at the well. At that point, the city installed an emergency diffused aeration system in the caisson to remove some of the TCE. Based on water quality data, the aeration system is able to remove 30 to 40 percent of TCE. With this diffused aeration system operating, concentrations of TCE in the water supply system have generally been below 50 ug/L.

In June and July 1982, the EPA's Technical Assistance Team (TAT) drilled 13 test wells in the vicinity of the municipal well without locating the source of contamination. Sampling of the test wells found varying concentrations of TCE and perchloroethylene (PCE). Chloroform (85 ug/L) and toluene (1 ug/L) were also identified in one well (T5) upgradient from the flume. No consistent results or identifiable plume for chloroform or toluene were found during the remedial investigations. It was assumed these were the result of field contamination of the samples and not considered further.

The remedial investigation of the Charlevoix site began in September 1983. Preliminary field work began in September and was completed in December with the installation and sampling of 12 borings and monitoring wells. The second major phase of field work began in July 1984 and included soil borings, monitoring well installation, water sample collection, water level data collection and air monitoring. In August 1984, additional water samples and water level data were collected. The final remedial investigation report was issued on February 7, 1985.

Although extensive soil borings and subsurface investigations were completed at the Charlevoix site no discrete source of contamination was found. In addition, no contaminants were found in the soil zone in any of the soil borings. Based on this fact only groundwater contamination is considered in this FS.

Data collected during the RI in December 1983 indicated that concentrations of TCE and PCE in the groundwater moving toward the water supply well were much higher than previously measured. A Focused Feasibility Study (FFS) was initiated in early 1984 because of the potential health hazard to Charlevoix residents presented by the contaminated drinking water supply. The purpose of the FFS was to evaluate Immediate Remedial Measures (IRM) that could be implemented to provide a safe drinking water supply. The FFS recommended that a Lake Michigan

water intake structure and filtration/flocculation plant be constructed to provide Charlevoix residents with a new water supply. Actions to implement the recommendation of the FFS were begun in June 1984. The expected completion data is now estimated to be August 1986.

## NATURE AND EXTENT OF SITE HAZARDS

### CONTAMINANTS

TCE and PCE are volatile, chlorinated organic compounds that are widely used in various industrial processes. TCE was first prepared in 1864 and found minor use as an anesthetic in 1933 to 1934. TCE is a primary component in degreasing operations, caffeine extraction from coffee, dry cleaning, and as a chemical intermediate in the production of pesticides, resins, waxes, varnishes and other specific chemicals. PCE, (tetrachloroethylene or perchloroethylene) is a clear, colorless, nonflammable liquid. It has been widely used as a dry cleaning agent, degreaser, chemical intermediate and a fumigant.

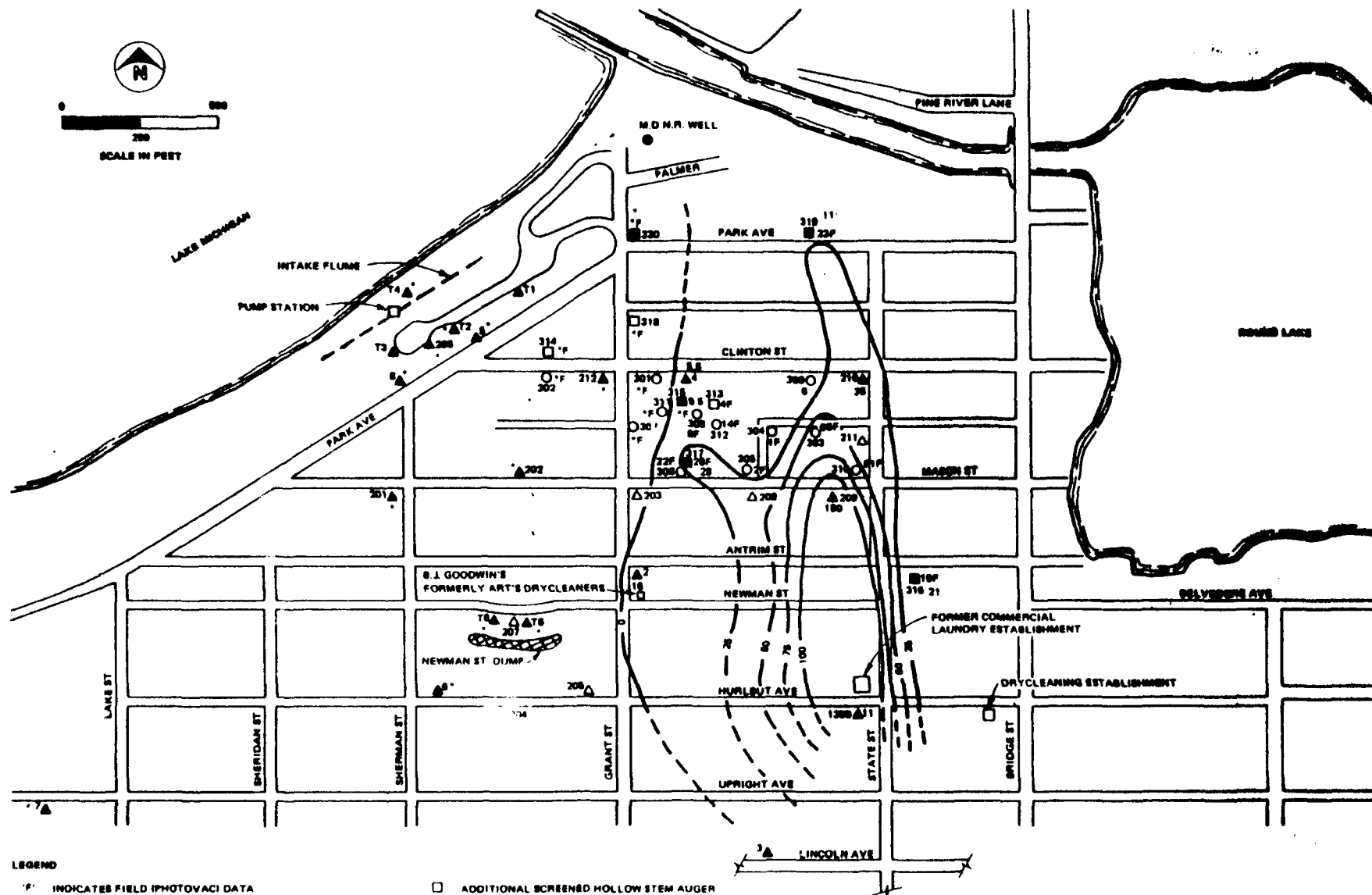
The U.S. EPA has recommended maximum contaminant levels (RMCL's) for trichloroethylene and tetrachloroethylene of "0" in drinking water. The Clean Water Act, water quality criteria for human health, drinking water only, established the  $10^{-6}$  risk level for TCE at 2.8 ug/L and for PCE at 0.88 ug/L. The  $10^{-6}$  risk level is defined as that concentration which would be expected to result in one additional incidence of cancer in a population of 1,000,000 persons exposed to ingestion of that concentration for an average lifetime of 70 years.

### GROUNDWATER PLUME GEOMETRY AND AQUIFER CONDITIONS

The area and volume of water contaminated with TCE and PCE at concentrations above the  $10^{-6}$  excess lifetime cancer risk level but less than 100 ug/L, is very difficult to define, largely because nearly every test hole, boring, or monitoring well detected some level of contamination. The areal extent of TCE contamination greater than 100 ug/L is approximately 243,000 ft<sup>2</sup> (Figure 2-4). The area contaminated by TCE at levels above the  $10^{-6}$  excess lifetime cancer risk level (2.8 ug/L) is approximately 3,000,000 ft<sup>2</sup> or 69 acres. The volume of water contaminated with TCE at concentration above the  $10^{-6}$  risk level, assuming 25 percent soil porosity and 70-foot aquifer thickness, is 393 million gallons.

PCE contamination greater than 25 ug/L in the study area is approximately 350,000 ft<sup>2</sup> (Figure 2-5). The southern end of the PCE plume is undefined and, therefore, volume calculations are rough estimates only. The area contaminated by PCE at levels above the  $10^{-6}$  risk level (.88 ug/L) is approximately





**FIGURE 2-6**  
**PCE CONCENTRATION MAP - JULY 1984**  
**CHARLEVOIX, MICHIGAN RI**



2,000,000 ft<sup>3</sup>, the volume of water contaminated with PCE above the 10<sup>-6</sup> risk level is approximately 260 million gallons. The boundaries of contamination are estimates, based on the distribution of the data, configuration of the groundwater flow system and areal geology (Figure 2-3).

The source of TCE in the groundwater was apparently located in the vicinity of the present day Charlevoix middle school play ground. Soil borings and monitoring wells found no evidence of a source existing now.

The source of the PCE contamination is located south of Hurlbut Street in the vicinity of Hurlbut and State Streets. No discrete source was discovered in this area but the density of soil borings and monitoring wells does not eliminate all possibility of a discrete source still existing.

The physical and chemical process governing the mobility and movement of TCE and PCE in soils and groundwater are dependent on many factors such as the soil type, organic matter and clay content, biological activity, and groundwater chemistry. Each of these factors influence the various transport mechanisms that determine the overall mobility of the contaminants. The cumulative, synergistic and interfering effects of these factors are difficult to treat in a nonlaboratory environment. The approach taken in this analysis is to address the contaminant mobility through groundwater flow analysis and aquifer-contaminant interaction through retardation coefficients for each contaminant of interest.

The retardation coefficient expresses the retarded velocity of each contaminant in relation to the velocity of groundwater flow. It incorporates the factors influencing transport mentioned previously into one coefficient that is divided into the velocity of groundwater flow. Appendix A provides the technical support for the retardation coefficients used in this report. TCE has a calculated retardation coefficient of about 1.9 while PCE has a calculated retardation coefficient of about 4.4. TCE will, therefore, move faster through the aquifer than PCE. It has been assumed that PCE and TCE will not undergo chemical degradation while moving through the aquifer nor will they be lost through volatilization or chemical fixation. If degradation were taking place, the chemical degradation products expected to be present would be either vinyl chloride or isomers of dichloroethene. These products were not found in water samples subjected to a broad scan for volatile organic compounds.

Using the previously mentioned retardation coefficients for PCE and TCE, and aquifer properties determined during the RI the velocity of contaminant movements is calculated to be approximately 0.4 foot/day for TCE and 0.2 foot/day for PCE (see Appendix A).

## GROUNDWATER DISCHARGE TO LAKE MICHIGAN

The present direction of movement of the contaminated groundwater is toward the water supply flume and the Lake Michigan shoreline. When the flume is replaced by the lake water intake structure, the groundwater and TCE and PCE will be discharged directly to Lake Michigan.

To estimate the average concentrations of PCE and TCE in the water and sediment near the shoreline area, the following assumptions were made:

- o The slope of the nearshore Lake Michigan lake bottom is 5 foot/100 feet.
- o The nearshore current velocity (monthly mean) is 0.16 foot/second (from Sato & Mortimer, 1975).
- o The TCE plume is 60 feet thick and 350 feet wide. The average concentration of TCE in groundwater is 500 ug/L (Figure 2-6).
- o The PCE plume is 25 feet thick and is 1,700 feet wide. The average concentrations of PCE in groundwater are 100 ug/L (Figure 2-7).
- o Once the contaminated groundwater reaches the water in the lake, the contaminant is evenly mixed within the discharge area.

Using these assumptions, three cases for each contaminant were analyzed. A representative example of the dilution calculations is listed in Appendix A utilizing the above assumptions. Case 1 assumed that groundwater flow was perfectly horizontal and that the discharge zone for the groundwater plume is controlled by the geometry of the lake bottom (500 feet for PCE, 1,200 feet for TCE). For case 2 the mixing zone was reduced to 300 feet based on research done by MacBride and Pfannkuch (1975). That is, there is a vertical component to the groundwater flow system. The same mass is being discharged in Case 2 as in Case 1, but it is discharged within 300 feet of the shore. Case 3 is similar to Case 2, except that the discharge zone has been reduced to 150 feet to provide for a worst case situation. The results of the analysis are presented in Table 2-1. Case 3 will be described in more detail in Chapter 3, entitled "Endangerment Assessment."

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Table 2-1  
CONCENTRATIONS OF TCE AND PCE IN LAKE MICHIGAN  
FOR THREE DIFFERENT SIZE DISCHARGE ZONES

	Width of Mixing Zone		
	Case 1 Full Plume <sup>a</sup>	Case 2 300 Feet	Case 3 150 Feet
TCE (ug/L)	0.008	0.134	0.54
PCE (ug/L)	0.0095	0.026	0.110

<sup>a</sup>For TCE = 1,200 feet, for PCE = 500 feet.

GLT441/114

## **Chapter 3** **ENDANGERMENT ASSESSMENT**

### **INTRODUCTION**

This endangerment assessment contains an evaluation of the potential human exposure, human health effects and environmental effects under a no action alternative after implementation of the initial remedial measure (IRM) of installing a Lake Michigan water intake and treatment plant for a public drinking water supply. Once implemented the IRM will eliminate further human exposure to VOC contamination through the existing public drinking water supply. This assessment considers potential future impacts assuming no other remedial actions to remove contaminants from the groundwater or land use restrictions are implemented which would limit access or exposure to contaminated groundwater.

The endangerment assessment begins with a discussion of the contaminants and their effects on humans and the environment. Following this, an endangerment assessment is presented for each potential exposure pathway at the Charlevoix site. The endangerment assessment presents exposure risk assessments for each of the contaminants. Finally, impacts on the biota are determined in the environmental exposure assessment.

Where applicable, comparisons are made of concentrations of the contaminant to relevant state and federal advisories, criteria, and standards. The assumptions and other sources of uncertainty inherent in the development of potential toxic or carcinogenic effects on the public health and environment are documented in this assessment.

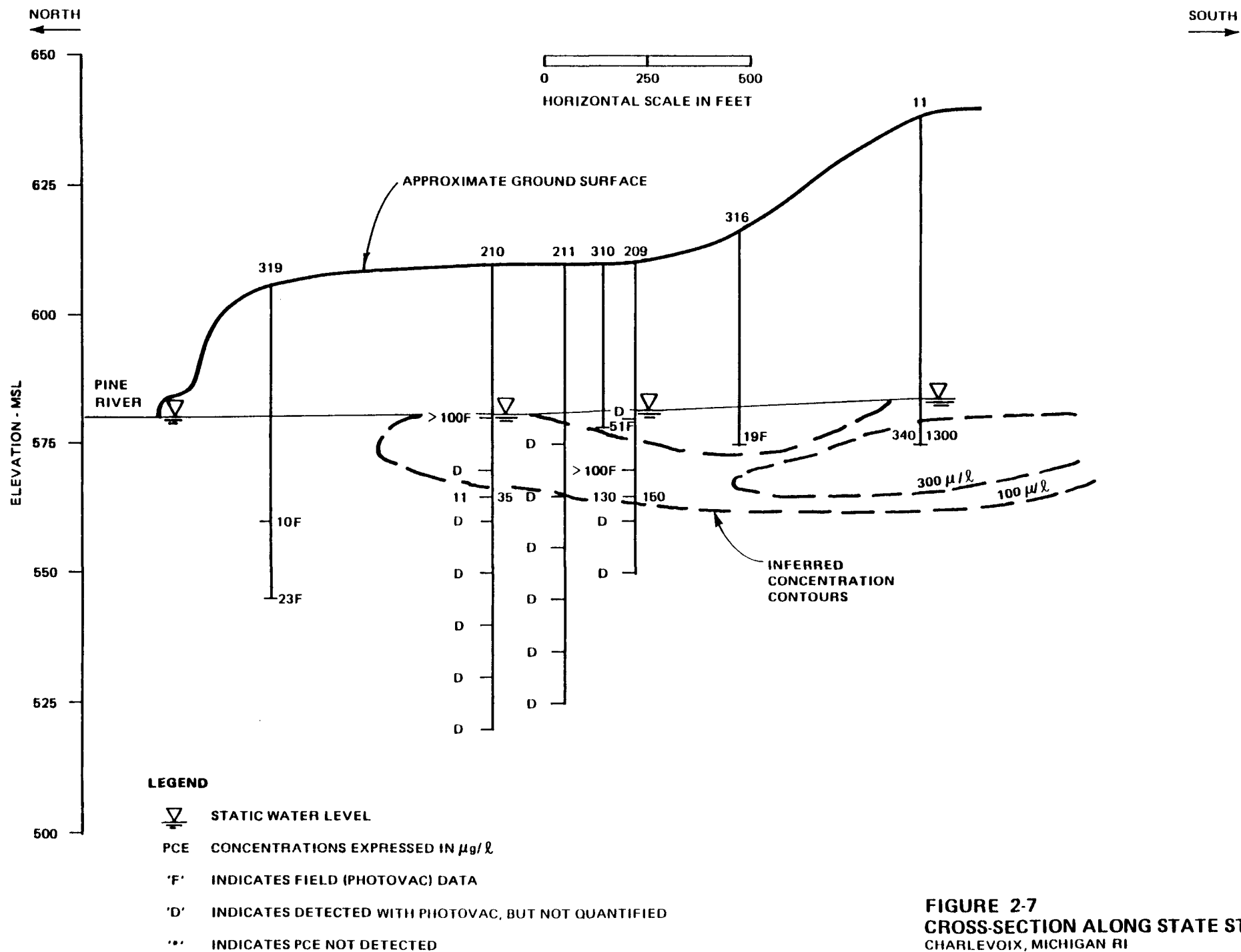
### **CONTAMINANT HAZARD ASSESSMENT**

The remedial investigation (February 1985) documented that the shallow sand and gravel aquifer is contaminated with levels of TCE and PCE as high as 960 and 1,300 ug/L, respectively. Areas underlain by the contaminated groundwater were mapped, but the exact source of the PCE contamination could not be determined. TCE contamination was found to originate from an area on the Charlevoix Middle School grounds.

Chemical hazard profiles are presented for TCE and PCE in Appendix B. TCE and PCE have been assigned a cancer potency value by the U.S. EPA Cancer Assessment Group (CAG) (U.S. EPA, 1984). Cancer potency measures the tendency of a chemical to induce formation of cancerous growth.

### **ENDANGERMENT ASSESSMENT**

The endangerment assessment for the Charlevoix site is based on the potential future exposure of residents to the volatile



organic compounds TCE and PCE.

Excess lifetime cancer risks are calculated for TCE and PCE using their cancer potency values (U.S. EPA, 1984). Excess lifetime cancer risk is defined as the incremental increase in the probability of getting cancer compared to the risk if no exposure to the contaminant occurred. For example an excess lifetime cancer risk of  $1 \times 10^{-6}$  would mean an increase in risk by one in a million. A  $10^{-6}$  risk is the level associated with the risk of getting one excess cancer per one million people exposed per standard 70-year lifetime. Excess lifetime cancer risk is estimated by multiplying an exposure level by a cancer potency value established by the EPA Cancer Assessment Group.

The subsequent analyses in this report are based on the following assumptions:

- o Chemicals are assumed not to degrade over time. The concentration does vary due to plume movement and dilution.
- o The exposure to contaminants varies over time.
- o The sources of exposure quantified are from ingestion and dermal absorption.
- o For ingestion, the absorbed dose is 100 percent of the intake.

#### POTENTIAL HUMAN EXPOSURE PATHWAYS

Based on the direction of groundwater flow (see Figure 2-3) and future potential use of the shallow glacial aquifer at the site, major pathways for human exposure and environmental exposure were identified.

Potential future use of groundwater is the first human exposure pathway evaluated in this assessment. The pathway would be from the potential future use of private wells. The probability of this occurring is unknown and has not been estimated in this endangerment assessment. Assuming, however, that the groundwater is used, exposure to contaminants would be from:

- o Ingestion of water
- o Dermal absorption from bathing
- o Inhalation of vapors released from the water during bathing and other uses

Current knowledge and data limit the ability to estimate risk to that from ingestion and skin absorption routes. For this study, the intake of contaminants via inhalation is considered, but it is not quantifiable with any certainty. (See Appendix B for discussion of exposure routes.)

The second human exposure pathway evaluated in this assessment is the recreational use of surface waters for swimming and sport fishing. Contaminated groundwater is likely to discharge into the surrounding surface water bodies in the area. These are Lake Michigan and Round Lake. The pathways of potential exposure would be through:

- o Accidental Ingestion of water during swimming
- o Dermal absorption during swimming
- o Ingestion of fish from contaminated surface waters

The third and fourth potential exposure pathways to TCE and PCE are direct contact with contaminated dust or vapors from exposed contaminated soils. This could potentially occur at the surface, or during excavation of construction projects.

#### GROUNDWATER

Ingestion from drinking contaminated groundwater is an important pathway for potential detrimental effects on human health. Although an IRM will be in place to supply public drinking water, no controls are in place to exclude inadvertent or intended future use of contaminated portions of the aquifer.

Data used for the groundwater contamination endangerment assessment from the RI report are presented in Appendix A and described in detail in Chapter 2.

For this analysis it is assumed that no new leachate is generated at the source areas and a well is placed north of Clinton Street between Grant and State Streets. The well would withdraw water from the contaminated portion of the aquifer, subjecting the water users to exposure to both TCE and PCE.

As shown in Table 3-1, the sum of health risks encountered from using the contaminated water for both drinking and bathing is  $4 \times 10^{-4}$ . This implies that if a population of 10,000 persons were exposed to this level of contamination for a period of 70 years, 4 additional incidences of cancer would be expected. This is unacceptably high based on current EPA policy. Present EPA policy is to reduce or limit human exposure to no more than a one in one million risk factor or  $10^{-6}$  risk level.



Table 3-1  
SUMMARY OF GROUNDWATER CONTAMINATION AND CANCER POTENCIES  
FOR POTENTIAL FUTURE USE OF A PRIVATE WELL

<u>Compound</u>	<u>Cancer<sup>a</sup> Potency (mg/kg-day)<sup>-1</sup></u>	<u>Average Concentration Over Lifetime (mg/L)</u>	<u>Lifetime Average Dose (mg/kg-day)</u>	<u>Excess Lifetime Cancer Risk</u>
<u>Ingestion</u>				
Trichloroethylene <sup>b</sup>	$1.9 \times 10^{-2}$	0.018	0.0006	$1 \times 10^{-5}$
Tetrachloroethylene <sup>b</sup>	$3.5 \times 10^{-2}$	0.131	0.004	$2 \times 10^{-4}$
<u>Dermal Absorption</u>				
Trichloroethylene <sup>b</sup>	$1.9 \times 10^{-2}$	0.018	0.0007	$1 \times 10^{-5}$
Tetrachloroethylene <sup>b</sup>	$3.5 \times 10^{-2}$	0.131	0.005	<u><math>2 \times 10^{-4}</math></u>
TOTAL				$4 \times 10^{-4}$

<sup>a</sup> U.S. EPA 1984

<sup>b</sup> Although EPA gives potencies, the International Agency for Research on Cancer (IARC) ranks this compound as Group 3 - "The Chemical cannot be classified as to its carcinogenicity to humans."

Table 3-2  
SUMMARY OF POTENTIAL FUTURE SURFACE WATER CONTAMINATION  
AND CANCER POTENCIES

<u>Compound</u>	<u>Cancer<sup>a</sup> Potency (mg/kg-day)<sup>-1</sup></u>	<u>Average Future Concentration (mg/L)</u>	<u>Lifetime Average Dose (mg/kg-day)</u>	<u>Excess Lifetime Cancer Risk</u>
<u>Water Ingestion During Swimming</u>				
Trichloroethylene	$1.9 \times 10^{-2} \text{ }^b$	0.00054	$5.4 \times 10^{-9}$	$1 \times 10^{-10}$
Tetrachloroethylene	$3.5 \times 10^{-2} \text{ }^b$	0.00011	$1.1 \times 10^{-9}$	$4 \times 10^{-11}$
<u>Dermal Absorption During Swimming</u>				
Trichloroethylene	$1.9 \times 10^{-2} \text{ }^b$	0.00054	$4.3 \times 10^{-7}$	$8 \times 10^{-9}$
Tetrachloroethylene	$3.5 \times 10^{-2} \text{ }^b$	0.00011	$8.8 \times 10^{-8}$	$3 \times 10^{-9}$
<u>Fish Consumption</u>				
		<u>mg/kg</u>		
Trichloroethylene	$1.9 \times 10^{-2} \text{ }^b$	0.0057	$3.9 \times 10^{-7}$	$7 \times 10^{-9}$
Tetrachloroethylene	$3.5 \times 10^{-2} \text{ }^b$	0.0034	$2.3 \times 10^{-7}$	<u><math>8 \times 10^{-9}</math></u>
TOTAL				$3 \times 10^{-8}$

<sup>a</sup> U.S. EPA 1984

<sup>b</sup> Although EPA gives potencies, the International Agency for Research on Cancer (IARC) ranks this compound as Group 3 - "The Chemical cannot be classified as to its carcinogenicity to humans."

Excess lifetime cancer risks were calculated using a lifetime average water ingestion rate (LAWI) of 0.035 liters per kilogram body weight per day and lifetime average daily dermal intake (LADDI) of 0.037 L/kg body weight per day. The derivation of these rates is shown in Appendix B. This assumes a 70 year lifetime. The potential health risks for ingestion and dermal absorption of this case are included in Table 3-1. This case represents a potential future use of the aquifer for potable water supply.

#### SURFACE WATER

The contaminant plumes extend from the southern most extent of the plume to the local groundwater discharge areas in Lake Michigan. The contaminated groundwater discharges to Lake Michigan at a relatively constant rate, adding both TCE and PCE to the lake water. The current groundwater problem then become a surface water problem. As this occurs, the most likely pathways for human exposure to the contaminants.

- o Accidental ingestion of water during swimming
- o Dermal absorption during swimming
- o Ingestion of contaminated fish from contaminated surface waters

To date, no surface water samples collected have indicated that surface water bodies in the area are contaminated with TCE or PCE. The following analysis is conservative in that groundwater reaching Lake Michigan in the future is assumed to have concentrations of TCE and PCE at the highest concentrations measured to date. The methods used to estimate the concentrations of PCE and TCE in the water near the shoreline groundwater discharge area and their associated risk levels are explained in Appendix A.

A human exposure analysis was performed (Table 3-2) based on the assumption that the maximum levels of TCE and PCE in the surface water could be 0.54 ug/L and 0.11 ug/L, respectively. The assumptions made were that children would swim 10 times per year for 15 minutes per swim and adults would swim 5 times per year for 15 minutes per swim (swimming in Lake Michigan is limited because of the year-round cold temperatures). The analysis includes both ingestion of water and dermal absorption (during swimming). Pertinent assumptions included a lifetime average water ingestion rate (LAWI) for swimming of 0.00001 L/kg-day and a lifetime average dermal absorption rate (LADDI) for swimming of 0.0008 L/kg-day.

Both TCE and PCE have been shown to accumulate in fish tissue (Verschwen, 1983). If the groundwater contaminated with TCE and PCE does reach Lake Michigan at the concentrations assumed for the human endangerment assessment from surface water, the fish species in the nearshore zone could bioconcentrate

TCE and PCE. The bioconcentration factor for TCE is 10.6 and for PCE is 30.6 (ICF, Environ, 1983). Therefore, if the maximum nearshore concentration of TCE is 0.54 ug/L, the concentration of TCE in fish tissue may be as high as 5.7 ug/kg. If the maximum concentration of PCE in the nearshore zone is 0.11 ug/L, the concentration of PCE in fish tissue may be as high as 3.4 ug/kg. Excess lifetime cancer risks from consumption of fish are given in Table 3-2. A lifetime average fish ingestion rate for adults (LAFI) of 0.069 g/kg-day was used.

## SOIL

Data used for the soil contamination endangerment assessment are presented in Table 3-3. Organic vapor analyses of soil samples from the potential source areas did not indicate that the soils are contaminated (two soil samples did show TCE concentrations, but these were samples from the groundwater saturated zone).

At present the exact source of the TCE and PCE contamination has not been located, but the general location, as defined by groundwater plumes (Figures 2-4 and 2-5), was determined in the RI. There is a potential for unrestricted future development under the no action alternative. Some values for health impacts through contact with contaminated soils are included in Appendix B. A further assessment will be performed if contaminated soils at the site are located or unearthed.

The environmental pathways of dust entrainment leading to exposure from ingestion, inhalation, and soil contact with the skin were not examined in detail. These pathways could increase potential exposure and the health risks if the source of TCE or PCE are inadvertently or intentionally excavated and exposed.

## AIR

The compounds of concern at the site, TCE and PCE, are both volatile. There may be areas at the site where contaminant vapors may be inhaled by humans or other animals, therefore a field inspection was performed to identify the presence of organic vapors. The inspection during the RI focused on areas overlying the suspected groundwater contaminant plumes and within enclosed spaces where vapors could build up. The results of the field inspection from the RI are presented in Table 3-4.

The inspection was conducted using an HNU PI-101 photoionizing organic vapor analyzer calibrated to benzene. The relative response for both TCE and PCE vapors, is approximately equal to 90 percent of the response for benzene on the HNU.

Table 3-3 (Page 1 of 2)  
FIELD SCREENING DATA FOR CONTAMINANT CONCENTRATIONS IN SOIL  
SAMPLES COLLECTED DURING THE RI

Boring Number	Split-Spoon Sample Number	Depth Below Ground Surface (Ft)	TCE Concentration (ug/L)	PCE Concentration (ug/L)	Comments
301	SS-1	5-7	1	0	Water table at 28 ft. TCE concentration in groundwater is 194 ug/L.
	SS-2	10-11.5	0	0	
	SS-3	15-16.5	1	0	
	SS-4	20-21	2	0	
	SS-5	25-26	45	0	
	SS-6	30-31.5	41	0	
302	SS-1	15-17	0	0	
	SS-2	20-21.5	<1	<1	
	SS-3	25-26	0	0	
	SS-4	30-31	0	0	
303	SS-1	2-4	<1	<1	
	SS-2	6-7.5	0	0	
	SS-3	10-12	0	0	
	SS-4	14-15.5	0	0	
	SS-5	18-19	0	0	
304	SS-1	2-4	0	0	
	SS-2	6-8	0	0	
	SS-3	10-12	0	0	
	SS-4	18-20	0	0	
	SS-5	22-24	0	0	
	SS-6	26-28	0	0	
305	SS-1	1-3	0	0	
	SS-2	5-7	0	0	
	SS-3	10-12	0	0	
	SS-4	15-17	0	0	
	SS-5	20-21	0	0	
	SS-6	25-26	<1	0	
306	SS-1	5-7	0	0	
	SS-2	10-12	0	0	
	SS-3	15-16.5	0	0	
	SS-4	20-21	0	<1	
	SS-5	25-26	<1	<1	

Table 3-3 (Page 2 of 2)

<u>Boring Number</u>	<u>Split-Spoon Sample Number</u>	<u>Depth Below Ground Surface (Ft)</u>	<u>TCE Concentration (ug/L)</u>	<u>PCE Concentration (ug/L)</u>	<u>Comments</u>
307	SS-1	5-7	0	0	
	SS-2	10-12	0	<1	
	SS-3	15-17	0	0	
	SS-4	20-22	0	0	
308	SS-1	5-7	0	0	Dark brown to black fill 0-12' fill.
	SS-2	10-12	<1	0	Dark brown to black fill.
	SS-3	15-17	0	0	
	SS-4	20-22	0	0	
	SS-5	25-27	<1	0	
309	-	-	-	-	No split-spoon samples collected, groundwater sample only.
310	-	-	-	-	No split-spoon samples collected, groundwater sample only.
311	SS-1	5-7	<1	<1	
	SS-2	10-12	0	0	
	SS-3	15-16.5	0	0	
	SS-4	20-21	0	0	
	SS-5	25-27	0	0	
312	SS-1	5-6.5	2	0	Dark brown fill.
	SS-2	10-12	0	0	
	SS-3	15-18.5	0	0	
	SS-4	20-21	0	0	
	SS-5	25-26	0	0	

The detection limit for both TCE and PCE is approximately 1 ug/L using the PHOTOVAC GC.

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Table 3-4  
FIELD INSPECTION SUMMARY  
(Page 1 of 2)

<u>Building or Location</u>	<u>Address</u>	<u>Date and Time Surveyed</u>	<u>Areas Surveyed</u>	<u>HHU Readings ppm-Equivalent to Benzene</u>	<u>Comments</u>
County Annex Building	203 Antrim St.	7/16/84-0900	Outside of building in yard	0.6	Background reading
			Basement		
			- bathroom ceiling	2.2	
			- utility closet	1.2	
			- Building Inspection Offices		
			- ceiling	2.2	
			- northeast office	3.0	
			- north room	2.0	
			- record storage room	0.5	
County Building	Antrim St.	7/16/84-0930	Outside of building in yard	0.2	Background reading
			Basement		
			- hall next to vaults	0.0	
			- boiler room workshop	0.4	
			- furnace room	0.2	
City Hall and Fire Station	Mason St.	7/16/84-0945	Basement		
			- east storage room	0.5-1.0	
			- Police storage room	6.0-12.0	Room poorly ventilated with several gasoline containers
			- outside of Police storage room	1.0	
			- crawl space near stairway	0.5	
			- women's lounge	0.5	
B.J. Goodwin's (formerly Art's Drycleaners)	230 Antrim St.	7/16/84-1020	Basement		
			- along walls	0.5-0.8	
			Back storage room		
			- general area	0.5	
			- 6-inch drain	300	Drains formerly used for dry- cleanings
			- small drains along west wall	10-120	No longer being used
			Back shed		
			- along dirt floor	0.5	
			Outside along edge of buildings	3.0-7.5	
Newman St. Dump Site	Newman St.	7/16/84-1110	Well T5	0.0	
			Surface soil around site	0.0	

Table 3-4  
(Page 2 of 2)

<u>Building or Location</u>	<u>Address</u>	<u>Date and Time Surveyed</u>	<u>Areas Surveyed</u>	<u>HNU Readings ppm-Equivalent to Benzene</u>	<u>Comments</u>
Charlevoix Middle School	Grant St.	7/16/84-1330	West Wing		
			- northwest corner crawlspace	0.3	4-feet below floor level Crawlspace all very dry and dusty
			- northwest corner crawlspace	0.3	
			East Wing		
			- north wall crawlspace	0.4	
			Basement		
			- boiler room and laundry room	0.3	Slight cleaning solvent odor
			- cleaning equipment storage room	1.0	
			- floor drain near north entrance to basement	0.3	
			Outside		
Winchester's Funeral Home	State St.	7/19/84-1600	- fuel oil tank vent	0.3	
			- playground storm sewer in the track infield	0.0-0.1	
			- monitoring well No. 4	0.0	
			- monitoring well No. 212	0.0	
			Basement		
			- general area, walls, floors	0.0	
			Garage		
			- general area	0.0	
			- floor drain	3.5	
			Metal garage behind house	0.0	
Jack Gordon Residence	206 Clinton St.	7/19/84-1630			
Rick Bieman Residence	204 Clinton St.	7/19/84-1645	Basement of house	0.0	
Mrs. Barry Wood Residence	207 Mason St.	7/19/84-1700	Basement and crawlspace of house	0.0	
	202 Clinton St.	7/19/84-1715	Shed and barn behind house	0.0	

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The inspection, conducted in and around the nine buildings and the Newman Street Dump site listed in Table 3-4, consisted of walking through the buildings carrying the HNU unit and surveying basements, crawl spaces, walls, corners, floors, and floor drains. Monitoring wells and the general ground surface were inspected near the Newman Street Dump. No significant concentrations of contaminants were noted except in the drain at the former dry cleaning establishment. The values measured in the drains are below the immediate danger of life and health values (IDLH) for TCE and PCE and exposure to concentrations that would exceed the threshold limit value (TLV) for either chemical in the respirable zone is doubtful.

#### ENVIRONMENTAL EXPOSURE

The federal criteria for the protection of freshwater aquatic life list the concentrations above which acute effects in aquatic life would be noted as 45,000 ug/L for TCE and 5,280 ug/L for PCE (U.S. EPA, 1980). These are five and four orders of magnitude higher than the maximum projected concentrations for TCE and PCE in the nearshore area of surface water. PCE has a long term or chronic criterion for protection of aquatic life of 840 ug/L (U.S. EPA, 1980), which is still three orders of magnitude higher than the projected value for PCE. Accumulation of TCE and PCE in fish, discussed in the human endangerment assessment, has not been documented as having adverse effects on fish.

Based on the foregoing, the aquatic life in Lake Michigan should not be adversely affected by the natural discharge of the contaminated groundwater to the lake.

#### SUMMARY

Given that the public water supply is being replaced and the present groundwater/lake water supply will be abandoned, the areas of concern for human exposure are limited to:

- o Groundwater
- o Surface water
- o Soil
- o Air

Based on the forgoing analyses, the potential for exposure of humans to TCE and PCE via surface waters at toxic concentrations is remote. The potential for carcinogenicity in humans due to ingestion or skin absorption while swimming would be low.

Since no significant contamination of surface soils was discovered, the potential for exposure of humans to TCE and PCE via soil ingestion, contact, or inhalation at toxic or po-

tential cancer causing concentrations is also remote.

The potential future exposure of humans to toxic or carcinogenic concentrations of TCE or PCE vapors is also slight since sampling efforts did not reveal any high concentrations.

The only potential future exposure for humans to high carcinogenic levels of TCE and PCE would be direct consumption of contaminated groundwater from wells located in the contaminated groundwater plumes.

No adverse impacts on the biota are anticipated for the no action alternative.

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## Chapter 4 REMEDIAL ACTION OBJECTIVES

### INTRODUCTION

The endangerment assessment for the Charlevoix site has concluded that the only significant potential public health hazards result from exposure to contaminated groundwater. There are minimal impacts to the biota in either Lake Michigan or Round Lake. The overall objective of remedial actions at the site should then be to minimize the potential risk to the public from direct consumption of the contaminated groundwater. Since it has been decided by U.S. EPA and MDNR to implement the construction of a new Lake Michigan water intake and treatment plant for the city water supply as an Initial Remedial Measure, the existing public health hazard from the existing water supply will be eliminated. A risk remains however of inadvertent use of the contaminated groundwater by individuals unaware of the hazard during the estimated time necessary for the plume to be naturally purged. The specific remedial action objective for the Charlevoix site is to minimize or eliminate this risk.

In addition to protecting public health it is desirable to evaluate methods and procedures to cleanup the aquifer and restore it to a useable resource. EPA has defined cleanup objectives in its Groundwater Protection Strategy (1984) for each of three aquifer classifications.

### AQUIFER CLASSIFICATION

The three aquifer classifications are as follows:

- o Class I Special groundwaters are those that are highly vulnerable to contamination because of the hydrological characteristics of the areas under which they occur and that are characterized by either of the following two factors:
  - Irreplaceable, in that no reasonable alternative source of drinking water is available to substantial populations
  - Ecologically vital, in that the aquifer provides the base flow for a particularly sensitive ecological system that, if polluted, would destroy a unique habitat
- o Class II These are all other groundwaters that are current or potential sources of drinking water and waters having other beneficial uses.

- o Class III Groundwaters not considered potential sources of drinking water and of limited beneficial use, are groundwaters that are heavily saline, (with total dissolved solids (TDS) levels over 10,000 mg/L) or are otherwise contaminated beyond levels that allow cleanup using methods reasonably employed in public water system treatment. These groundwaters also must not migrate to Class I or II groundwaters or have a discharge to surface water that could cause adverse effects on human health or the environment.

The contaminated aquifer underlying Charlevoix does not meet the first criterion for a Class I aquifer because a large source of drinking water is readily (and cost-effectively) available from Lake Michigan. It does not meet the second criterion for a Class I aquifer since there is no impact from the plume on the biota as established in the endangerment assessment.

The aquifer also does not meet the requirements for Class III since it is not heavily saline and it could be cleaned up using proven technology.

As a result, the aquifer is a Class II aquifer. EPA's cleanup objectives for Class II aquifers under CERCLA and RCRA are to develop remedial actions that protect human health and the environment. Typically, remedial action alternatives include:

- o cleanup of the groundwater
- o provision of alternate water supplies
- o plume management

The initiation of a remedial action is normally triggered by a threat<sub>5</sub> to the environment or to human health which exceeds the  $10^{-5}$  risk level. Response actions are<sub>6</sub> normally designed to reduce the health risk to below the  $10^{-6}$  risk level.

The remedial action objective of minimizing the public health risk associated with potential future use of the contaminated groundwater in Charlevoix is consistent with the CERCLA and the EPA groundwater protection strategy objective. Minimizing this potential risk may be done by either removing the contaminated water or by isolating the contamination through physical or institutional means. The various options for achieving this objective are discussed in the following sections.

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## Chapter 5 ALTERNATIVE DEVELOPMENT AND SCREENING

### INTRODUCTION

During the remedial investigation one of the soil borings or monitorings encountered significant soil contamination above the water table, nor was any discrete source, such as a tank or drums found in the Charlevoix Middle School grounds. The data gathered during the RI (see RI report, February 1985) indicate that there is no current source of contamination and that the origin of the contaminated groundwater was either a single spill or a source that was subsequently removed. Because the source of PCE and TCE contamination is believed to no longer exist, only remedial actions for management of contaminated groundwater or migration will be considered. Remedial actions are developed here to meet the objective of minimizing public health risk associated with potential future use of the contaminated groundwater.

The alternative development and screening process involves the following steps:

- o Identifying general response actions
- o Selection and screening of remedial technologies
- o Development of alternatives
- o Screening of alternatives

The first three steps are discussed in the following section.

### ALTERNATIVE DEVELOPMENT

#### GENERAL RESPONSE ACTION DEVELOPMENT

General response actions potentially meeting the remedial action objective include:

- o No action
- o Limited action, which includes monitoring, and regulation
- o Extraction of the contaminated groundwater via pumping
- o Treatment of extracted contaminated groundwater

Containment of the contaminated groundwater by physical barriers such as slurry walls was also considered as a general response

action but was rejected because it does not adequately meet the objective of protecting against future use of the contaminated groundwater. Whereas it would prevent further migration of the plume and thus reduce the number of residences located above the plume, it would not reduce the risk for the areas overlying the present plume.

#### SELECTION AND SCREENING OF REMEDIAL TECHNOLOGIES

Each of the general response actions has associated remedial technologies. Remedial technologies are listed below for each general response action.

- o No action
- o Limited action
  - Groundwater monitoring and analysis
  - Regulatory isolation of plume area
- o Extraction of contaminated groundwater
  - Extraction wells
  - Extraction wells in combination with shallow injection wells
- o Treatment of contaminated groundwater
  - Granular activated carbon adsorption
  - Air stripping
  - Steam stripping
  - Physical/chemical treatment
  - Biological treatment
  - Oxidation

Screening of remedial technologies is based on the following evaluation criteria:

- o Data on physical site conditions that preclude, restrict, or promote the use of a specific technology
- o Chemical and physical characteristics of contamination that affect the effectiveness of a remedial technology
- o Inherent nature of a technology such as performance record, reliability, and operating problems
- o The relative costs of the technologies to allow comparison of financial impact. Costs are not quantified at this screening level but rather are defined relative to other technologies

Each remedial technology is described below and evaluation criteria of greatest importance to the technology discussed.

#### Limited Action

The objective of this technology is to allow detection and monitoring of the plume under the limited action alternative until the contaminant plume has migrated and discharged to either Lake Michigan or Round Lake. It would be designed to match the RCRA groundwater monitoring requirements of owners and operators of hazardous waste disposal facilities contained in 40 CFR, Part 264, Subpart F-Groundwater Protection. The existing network of upgradient and downgradient monitoring wells would be used. Lake Michigan and Round Lake will be sampled at the same time. Sampling and analysis for TCE and PCE would occur semiannually until the contaminant levels drop to some predefined acceptable level. Land use and deed restrictions would be implemented to prohibit well drilling in the plume area.

The technology for groundwater monitoring and analysis is a well proven method for detecting and tracking contaminant plumes. There are no site or waste characteristics or technological problems that would preclude its use and with the support of the city and state, appropriate restrictions could be implemented. Costs over the life of the monitoring effort would be lower than for the other remedial technologies. The technology will be retained for further analysis.

#### Extraction Wells

Extraction wells would be employed as part of the general response action of extraction of contaminated groundwater.

This technology would involve the installation and operation of wells, pumps, and collector pipes to allow removal of contaminated water for treatment or disposal to Lake Michigan.

When properly designed and constructed, the technology is reliable, effective, and durable. It is easy to install and applicable to site conditions in Charlevoix. Most of the cost is associated with operation and maintenance. The relative cost of this technology is not prohibitively large. It will be retained for further analysis.

#### Extraction Wells with Shallow Injection Wells.

This technology involves extraction as described in the preceding alternative and the addition of water treatment and shallow injection wells for water disposal. This remedial technology requires use of a treatment technology to reduce contaminants to acceptable levels (2.8 ug/L for TCE and 0.88 ug/L for PCE) prior to reinjection. For this analysis,

it is assumed that the level of treatment necessary before reinjection of the extracted water would be permitted is equivalent to the cleanup goal of reducing the health risk to below the  $10^{-6}$  risk level. Some alternate level of treatment less stringent than the  $10^{-6}$  risk level may be acceptable, such as a water quality criteria based on the technology chosen for treatment, i.e., a technology based criteria. However, whatever level of treatment is selected would have to be acceptable to criteria within the appropriate Michigan regulations and the federal underground injection control program, 40 CFR Part 146. The most restrictive interpretation of these programs indicates that the  $10^{-6}$  risk level would be the level of cleanup required, and this is the cleanup goal used in this analysis. The extraction-reinjection system involves the installation of extraction wells down gradient from the plumes, injection wells upgradient from the plumes and a air stripping or carbon adsorption treatment system prior to reinjection. The extraction injection system involves installation of wells, a pump station, treatment system and distribution piping to allow treated water to be restored to the shallow groundwater system upgradient of the existing contamination plume.

Groundwater reinjection upgradient of the existing contamination plume would increase the rate of groundwater flow to the extraction wells. At the higher induced groundwater flow, the operational life of the extraction and treatment system would be reduced, thus reducing operation and maintenance costs.

The reduction in O&M costs of the extraction with reinjection system however is offset by the increased capital costs of the necessary injection wells, pump station and distribution piping. The relative cost of this alternative would be similar to extraction wells with the same treatment system. Because this remedial technology requires a treatment system and it is not expected to offer cost savings, it will not be retained for further analysis.

#### Granular Activated Carbon Adsorption

This technology involves pumping extracted groundwater through a bed of granular activated carbon (GAC) where close contact with the surface of the carbon grains promotes the adsorption of contaminants. The activated carbon has a very high specific surface area and is able to absorb a wide variety of organic substances. Given sufficient contact time GAC treatment can remove in excess of 99 percent of TCE and PCE present in water.

The technology is effective and durable for a wide range of contaminants. Carbon adsorption achieves a high level of contaminant removal and is capable of producing water that



is of drinking water quality. Installation difficulty is comparable to other onsite treatment technologies, but operation is somewhat more difficult. Monitoring of the effluent water quality is particularly important to detect exhaustion of the adsorptive capacity of the carbon and contaminant breakthrough.

The advantages of activated carbon include:

- o Its ability to efficiently remove concentrations of a wide variety of organic substances from water supply
- o Its successful history involving full-scale water and wastewater treatment plant facilities
- o The ability to regenerate and reuse the adsorbent
- o No sludges or residues that are difficult to dispose of
- o Does not create additional emissions requiring treatment (such as air emissions)

The main disadvantage of activated carbon is the cost of carbon replacement or regeneration.

Although this technology may be more expensive than other technologies such as air stripping its relative cost is still roughly comparable. It will be retained for further analysis.

#### Air Stripping

The air stripping process mixes large volumes of air with water in a packed column, or through diffused aeration, to promote the transfer of volatile organic compounds (VOC's) into the air. In a packed column, water is pumped into the top of the column where it cascades down over loosely packed inert media while air is pumped upward through the column. The treated water is collected in a wet well below the tower and pumped to the receiving water body of POTW. In diffused aeration, air is introduced near the bottom of a basin and bubbling results in the transfer of VOC's from the water to the air. The State of Michigan may require that VOC's not be released into the air but must be adsorbed onto vapor phase carbon absorption scrubbers that must latter be disposed of.

The technology has good durability and has been proven effective in removing TCE and PCE. Also, this technology is easy to install and implement. Capital and operation and maintenance costs associated with this technology are moderate. It will be retained for further analysis.

### Steam Stripping

This technology is similar to air stripping except that steam is pumped into the stripping column with, or in place of, air. Steam stripping incorporates heat to promote the transfer of VOC's or more difficult to strip compounds from liquid into the gas. The gases are then passed through carbon filters before discharge. Additional mechanical equipment, boilers, and distribution systems are needed, making durability and ease of installation less than air stripping and substantially increasing cost.

In full scale installations for removal of readily strippable compounds such as TCE and PCE, steam stripping is markedly inferior to air stripping since it performs a similar function at much higher capital and operation and maintenance cost. Also, it requires relatively large energy inputs. For these reasons, steam stripping will not be retained for further analysis.

### Physical/Chemical Treatment

Physical/chemical treatment of domestic water supplies generally consist of such conventional processes as chemical coagulation, flocculation, sedimentation, and filtration. This type of treatment is not considered effective for removing dissolved volatile organic compounds. Studies of several full-scale conventional water treatment plants indicate no significant removals through the plant for tetrachloromethane, 1,2-dichloroethane, trichloroethene, and tetrachloroethene. Therefore, the conclusion is that conventional physical/chemical water treatment would be ineffective for removal of TCE and PCE. This technology will not be considered further.

### Biological Treatment

Biological treatment has been applied on a limited scale to the cleanup of several contaminated groundwater resources. Specially developed bacteria are cultivated to feed on the specific contaminants in situ or in surface reactors. These processes are typically proprietary and require pilot work and development of the bacterium strain. Experience to date has been with small systems operating at a few gallons per minute. They offer a potential cleanup alternative where the contaminants are suitable food for the bacteria, where the contaminants are in the right concentration range for the bacteria, and where cleanup time is not a problem.

Bacteria are not particularly effective on PCE and TCE (Swanwich and Foulkes, 1971) and the concentration of organics is well below the range needed for operation. Also for biological breakdown to proceed anaerobic conditions are required and as a result of this breakdown vinyl chloride is produced

which is more hazardous than either TCE and PCE. Biological treatment would not be able to meet the cleanup objectives and will not be considered further.

### Oxidation

Two general types of oxidation processes are available for treating organic contaminants in water: chemical oxidation and thermal oxidation. Chemical oxidation uses an oxidizing agent such as chlorine, ozone, hydrogen peroxide, or potassium permanganate to breakdown the organic constituents by breaking the chloride-hydrogen bonds or chlorine-carbon bonds. Thermal oxidation breakdown the contaminants through the application of heat in the presence of oxygen.

A major feature of oxidation processes is that they have the potential to destroy the contaminants instead of moving them to another phase for disposal. In theory, this removes them from further environmental considerations. However, such oxidation reactions are not always complete in actual practice. Incomplete oxidation of organic contaminants causes the formation of new compounds that may be as harmful to the environment or to human health as the original constituents. The lack of effectiveness of oxidizing trace substances in a relatively large flow stream and the potential formation of hazardous byproducts precludes oxidation from further consideration.

### Remedial Technology Screening Summary

A summary of remedial technology screening is presented in Table 5-1. Remedial technologies retained for further analysis for each of the general response actions are:

- o No action
- o Limited action
  - Groundwater monitoring and analysis
  - Regulatory isolation of plume area
- o Extraction of contaminated groundwater
  - Extraction wells
- o Treatment of contaminated groundwater
  - Granular activated carbon adsorption
  - Air stripping

Table 5-1  
REMEDIAL TECHNOLOGY SCREENING SUMMARY

General Response Actions	Remedial Technologies	Site Characteristics	Waste Characteristics	Technical Reliability, Operation, and Performance	Relative Cost	Conclusion	Comments
No Action	--	--	--	--	--	Discard	Does not address RA objective.
Limited Action	Groundwater Monitoring and Analysis	No limitations	No limitations	High	Low	Retain	--
Extraction of Contaminated Groundwater	Extraction Wells	No limitations	No limitations	High	Low	Retain	--
	Extraction With Shal- low Injection Wells	No limitations	No limitations	Moderate	Moderate	Eliminate	Must be used in conjunction with a treatment technology.
Treatment of Contaminated Groundwater	Granular Activated Car- bon Adsorption	No limitations	Effective in transfer- ring VOC's at ppb levels to carbon	High	Moderate	Retain	--
	Air Stripping	No limitations	Effective in transfer- ring VOC's at ppb levels to air	High	Moderate	Retain	--
	Steam Stripping	No limitations	Effective in removing VOC's at ppb levels	High	High	Eliminate	More suitable for semivolatiles. Higher cost for similar effectiveness in eliminating VOC's.
	Physical/Chemical	No limitations	Not effective in removing VOC's	Moderate	Moderate	Eliminate	Lack of effectiveness in removing VOC's.
	Biological Treatment	No limitations	Not effective in in removing VOC's at ppb levels	Moderate	Moderate	Eliminate	Lack of effectiveness in removing VOC's at low concentrations. Hazardous by products.
	Oxidation	No limitations	May form hazardous byproducts	Moderate	High	Eliminate	High cost and potential formation of hazardous byproducts.

## REMEDIAL ACTION ALTERNATIVES

The surviving remedial technologies are used to assemble remedial action alternatives that will satisfy the overall objective of minimizing the potential future risk to the public from direct consumption of the contaminated groundwater.

Four remedial action alternatives have been developed that satisfy the objectives discussed above. They are:

- o Limited Action
- o Plume Extraction with Discharge to Lake Michigan
- o Plume Extraction with Air Stripping Treatment
- o Plume Extraction with Carbon Adsorption Treatment

The Limited Action alternative allows the plume to naturally migrate to, and disperse in Lake Michigan over an estimated period of 50 years. It includes a semiannual groundwater sampling and analysis program so that the plume can be monitored throughout the natural purging period and zoning to prohibit new wells in the sand and gravel aquifer in the plume area. This alternative has the lowest cost of all alternatives.

The remaining alternatives were developed with the intent of reducing the period required for groundwater cleanup. The first of these, Plume Extraction with Discharge to Lake Michigan, does not include treatment of the extracted contaminated groundwater. Monitoring and permit requirements would be greater than that required for the limited alternative action due to the Lake Michigan discharge.

Plume Extraction with Air Stripping Treatment utilizes identical plume extraction facilities as the previous alternative but follows it with air stripping treatment to reduce TCE and PCE concentrations. The treated groundwater is then discharged to Lake Michigan. This alternative has a higher cost but lower public health risk than the previous alternative. MDNR water quality effluent limits would have to be met as well as NPDES and CERCLA criteria. The  $10^{-6}$  risk level has been chosen as the cleanup goal.

Plume Extraction with Carbon Adsorption treatment is similar to the air stripping alternative with only the treatment technology varying. Effluent criteria would also be the same and the alternative would offer a similar public health risk as the air stripping alternative with the additional benefit that no air emissions occur.

## ALTERNATIVE SCREENING

The purpose of alternative screening is to reduce the number of alternatives developed to allow those that remain to be

analyzed in detail. Because technology screening was able to reduce the number of feasible technologies, it was necessary to develop only four remedial action technologies. As a result, further screening of alternatives is not necessary and each alternative will be analyzed in detail in the subsequent chapter.

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## Chapter 6 DETAILED ANALYSIS OF ALTERNATIVES

### INTRODUCTION

In this chapter, the four remedial action alternatives are analyzed in detail and compared so that a suitable alternative that adequately protects the public health, welfare and the environment may be chosen. The evaluation criteria are first explained followed by descriptions of the alternatives and analysis of the criteria for each.

### EVALUATION CRITERIA

The following considerations will be used in the detailed analysis of alternatives:

- o Public health evaluation--endangerment to human health via exposure through ingestion of water, dermal absorption, inhalation of volatiles and ingestion of contaminated fish
- o Environmental assessment--endangerment to biota via exposure to contaminated water
- o Technical evaluation--evaluation of performance (effectiveness in meeting effluent criteria or other objectives and useful life), reliability (operation and maintenance requirements and demonstrated reliability), implementability (constructability and time to implement), and safety (operator and nearby resident's safety from fire, explosion, etc.)
- o Institutional issues--compliance with federal, state, and local standards, specifically including NPDES, POTW, and Clean Air Act permitting. Also, compliance with criteria and guidance in the EPA Groundwater Protection Strategy, Recommended Maximum Contaminant Levels (RMCL's), Health Advisories and EPA Water Quality Criteria (WQC). Other issues to be evaluated include public involvement, community effects, and historic and archaeological sites.
- o Cost--capital, operation and maintenance, and present worth costs (assuming a 10 percent interest rate)

## ALTERNATIVE A LIMITED ACTION

### DESCRIPTION

The Limited Action alternative would not involve active clean-up of the contaminated groundwater plume. It would allow the plume to naturally migrate and disperse in Lake Michigan. This is estimated to take approximately 50 years. During this period the plume would be monitored through a semiannual groundwater and lake water sampling and analysis program.

Legislative action and deed restrictions would be required to protect against future use of the contaminated groundwater. Specifically restricted would be use of any existing wells, installation of new wells, or a return to the existing municipal well in Charlevoix.

The monitoring program would include 10 observation wells selected from the existing monitoring well network based on their projected usefulness in monitoring the contaminant plumes' movements. A lake sample will be taken from Lake Michigan and from Round Lake. The lake samples will be compared to a baseline study conducted in 1982 by MDNR of Lake Michigan and Round Lake which did not detect any contaminants at that time. Sampling and analysis will continue until the contaminant levels reach some predetermined acceptable levels.

### PUBLIC HEALTH EVALUATION

The Endangerment Assessment evaluated public health effects of the no action alternative in detail and found that the health hazard for exposure of humans to TCE and PCE via surface waters is insignificant. A health hazard does exist for lifetime contact and ingestion of the contaminated groundwater. No other wells in the contaminated area other than the city well are presently in use for drinking water. Since future use will be officially restricted until the plume naturally purges, the only hazard remaining is from the unintentional or intentional illegal drilling of a well for private use. This is considered a remote possibility due to the city environment and the widespread community awareness of the problem.

### ENVIRONMENTAL ASSESSMENT

The Endangerment Assessment also evaluated environmental effects of the no action alternative and found that aquatic life (the only biota potentially affected) would not be adversely affected by the dispersion of the contaminated groundwater plume in Lake Michigan. Criteria for the protection of aquatic life are three to five orders-of-magnitude higher than the projected concentrations of TCE and PCE in nearshore



Lake Michigan.

#### TECHNICAL EVALUATION

This alternative employs relatively little technology. The technology that is used, groundwater and lake water sampling and analysis is a well proven method for detecting and tracking contaminant plumes. If any significant alterations in contaminant migration direction occur the monitoring program will be able to detect it so that appropriate response actions, if any, can be taken. Implementability will be immediate since the monitoring well network is presently in place.

Safety considerations of this alternative relate to the possibility of hazardous vapors being released from the monitoring wells. Vapors will not reach hazardous concentrations the wells since each will have a locking cap with a vent for the purpose of maintaining atmospheric pressure. When the well is open during sampling, the sampling crew will monitor the air for hazardous levels of organic vapors.

Overall the technical evaluation of the limited action alternative did not find any negative impacts associated with the performance, reliability, implementability or safety of the alternative. Since all alternatives will employ a similar monitoring program the evaluation pertains to each.

#### INSTITUTIONAL ISSUES

Federal, state, and local regulations generally do not apply to the limited action alternative because they primarily regulate proposed actions. Laws and policies that address existing conditions, rather than proposed actions, are the Resource Conservation and Recovery Act (RCRA), the U.S. EPA Groundwater Protection Strategy (GWPS), and the Water Resources Commission Act 245.

RCRA regulates facilities used for treatment, storage and/or disposal of hazardous wastes. This act is not expected to be applicable at Charlevoix because no such facility is involved and no source of the contamination is believed to currently exist. RCRA guidance on groundwater might be relevant but other EPA regulations may be more pertinent to the site.

The groundwater protection strategy has as a goal clean-up of groundwater to drinking water standards or to background levels for Class II aquifers. However, the GWPS recognizes that in some cases alternatives to groundwater clean-up and restoration may be appropriate for Class II aquifers.

The social impact on the community is also an issue of importance for the Limited Action alternative. The alternative

should be well received since a clean source of drinking water will be provided under the IRM and no significant impacts on public health or the environment are anticipated.

#### COST ANALYSIS

Costs of this alternative are associated with monitoring of the contaminant plumes through a semiannual groundwater and lake water sampling and analysis program. Samples will be collected from the 10 observation wells and two lake sample locations by a sampling team consisting of an engineer and a technician. It is estimated that sampling will take approximately 3 days to prepare equipment, travel to the site, collect the samples, and send them to the laboratory for analysis. Labor costs are estimated at \$1,800 with travel, equipment, and lab analysis, bringing the total to approximately \$8,600 per trip. The cost of two trips per year would, therefore, be approximately \$17,000. Table 6-1 represents the present worth costs on an annual basis for 30 years. Legislative costs incurred in the development of aquifer restrictions are not incorporated in this estimate.

#### ALTERNATIVE B PLUME EXTRACTION WITH DISCHARGE TO LAKE MICHIGAN

##### DESCRIPTION

This alternative would withdraw the contaminated groundwater plume and convey it to Lake Michigan for direct discharge. The contaminated groundwater would not be treated.

The analysis used to refine the number, location, and pumping rates of extraction wells required for capture and removal of contaminated groundwater is discussed in the following section entitled Well Placement Analysis. The required duration of pumping is also analyzed as it relates to treatment duration and level of clean-up in the section Groundwater Contamination Removal Rates.

##### Well Placement Analysis

The analysis is based upon the two VOC plumes described in the Chapter 2 sub-section entitled "Groundwater Plume Geometry and Aquifer Conditions."

The constraints on plume extraction with wells are the aquifer properties, the desired time to purge each pore volume, and the number of wells economically feasible to extract the plume. Several wells closely spaced can have the same effect as one or two wells farther apart but pumping at higher rates. The pumping rate and separation distance of each well are limited by the aquifer hydraulic conductivity, regional gradient and aquifer thickness. Closely spaced wells allow shorter travel distances for the contaminants but require

**Table 6-1**  
**GROUNDWATER MONITORING COSTS**  
**AND MONITORING WELLS**

Capital Expense	\$ 0
O&M 1 Year	17,000
Travel	1,500
Lab Analysis	12,000
Expendable Equipment	500
Labor	<u>3,000</u>
TOTAL PRESENT WORTH (at 30 years at 10 percent)	\$160,140

Wells to be Monitored (See Figure 2-3)

<u>Well No</u>	<u>Frequency</u>
T-1	Semiannually
T-2	Semiannually
T-4	Semiannually
209	Semiannually
212	Semiannually
305	Semiannually
309	Semiannually
318	Semiannually
319	Semiannually
320	Semiannually

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more wells to capture the entire plume.

Based on the remedial action objective of minimizing the time the contaminants remain in the aquifer, a pumping scheme was analyzed which maximizes rate of flushing of the aquifer and therefore minimizes clean-up time. The maximum rate of flushing is approximately one plume volume per year. Removing one plume volume in less than a year requires pumping rates that the aquifer cannot maintain without substantial drawdowns. A more practical pumping rate which would allow one plume volume to be exchanged every 3 years would not significantly improve clean-up times over natural flushing rates. Detailed analysis including modeling of the aquifer system is required to optimize the well extraction system. The level of detail here is sufficient for comparison purposes with the other alternatives and for preliminary cost analysis.

Two extraction wells are proposed to capture the two intersecting plumes of TCE and PCE shown on Figures 2-4 and 2-5. Regional gradients and velocity calculations of the combined contaminant plumes indicate that a combined pumpage rate of approximately 750 gpm will be necessary to capture the plumes. Using two wells, each pumping 375 gpm, a combined capture zone would then be approximately 2,750 ft. The widths of both the TCE and PCE plumes is approximately 2,600 ft. The above pumping rates therefore would conservatively produce the desired capture zone dimensions. Detailed analysis of aquifer properties and well interference effects to minimize pumping and clean-up time would be conducted if this option is implemented.

#### Groundwater Contamination Removal Rates

An estimate of the movement of contaminants from the aquifer to the extraction wells is necessary to evaluate the length of time extraction and treatment will be necessary. Movement of the contaminants is governed by groundwater flow, dispersion, diffusion, and contaminant/aquifer interactions. Accurate prediction of removal of the plume as a whole is difficult.

To estimate the concentrations of the contaminants from the extraction wells for evaluation of treatment technologies, the following simplifying assumptions were used:

- o The retardation coefficient values are constants
- o There is no continuing source of groundwater contamination
- o Chemical degradation of the contaminants does not occur

- o Rates of sorption/desorption reactions are fast relative to induced groundwater flow velocities
- o Extraction of contaminated water will undergo some dilution by mixing with non-contaminated and low contaminated groundwater

The change in concentration with time is then dependent on the flushing out of contaminated water and the desorption of contaminants absorbed onto the aquifer materials. The rate of groundwater movement under the proposed pumping scheme is relatively constant at any point in the aquifer, however, the degree that the contaminants are desorbed by the aquifer varies depending on the contaminant's partitioning coefficient. If the partitioning coefficient is large, more of the contaminant is held on the soil and released more slowly into the groundwater, therefore, requiring longer clean-up times. Figures 6-1 and 6-2 represent the range of expected concentrations at an extraction well located near the center of each plume over time.

To account for dilution and mixing effects of pumped withdrawal of the contaminated groundwater with the surrounding uncontaminated groundwater, average concentrations rather than peak concentrations of TCE and PCE were used as starting values at the extraction wells. The method of estimating the concentrations is detailed in Appendix A.

#### Summary of Description of Alternative

Based on the foregoing discussion the Plume Extraction with Discharge to Lake Michigan alternative will include the following components:

- o Two extraction wells 80 feet deep, placed north of the center of the TCE and PCE plumes.
- o Each well will pump at 375 gpm continuously with occasional shut down for maintenance or pump replacement.
- o Pumping is estimated to be necessary for 30 years to reduce TCE and PCE concentrations in the aquifer to the  $10^{-6}$  risk level concentration.
- o Extracted groundwater would be pumped under pressure a distance of 2,500 feet to discharge in Lake Michigan.
- o Monitoring requirements would be similar to the Limited Action alternative with additional bioassay monitoring in the discharge zone.

- o Land use and deed restrictions similar to the Limited Action Alternative would be necessary.

Piping to Lake Michigan under pressure is necessary due to health hazards associated with volatilization of PCE and TCE that would occur in a gravity sewer traversing Charlevoix. The discharge location would be located a sufficient distance from the new Lake Michigan water supply intake to prevent the surface water discharge plume from reaching the intake.

#### PUBLIC HEALTH EVALUATION

The groundwater and surface water are potential exposure pathways for this alternative. The endangerment to public health via the groundwater exposure pathway is similar to that discussed for the Limited Action alternative. The most significant threat the future illegal domestic use of contaminated groundwater however, would be reduced in direct proportion to the reduced number of years until the plume reaches safe levels. Under the Limited Action alternative this requires 50 years as compared to the estimated 30 years required under this alternative.

This alternative, however, introduces untreated contaminated groundwater directly into Lake Michigan. Potential surface water exposure pathways include:

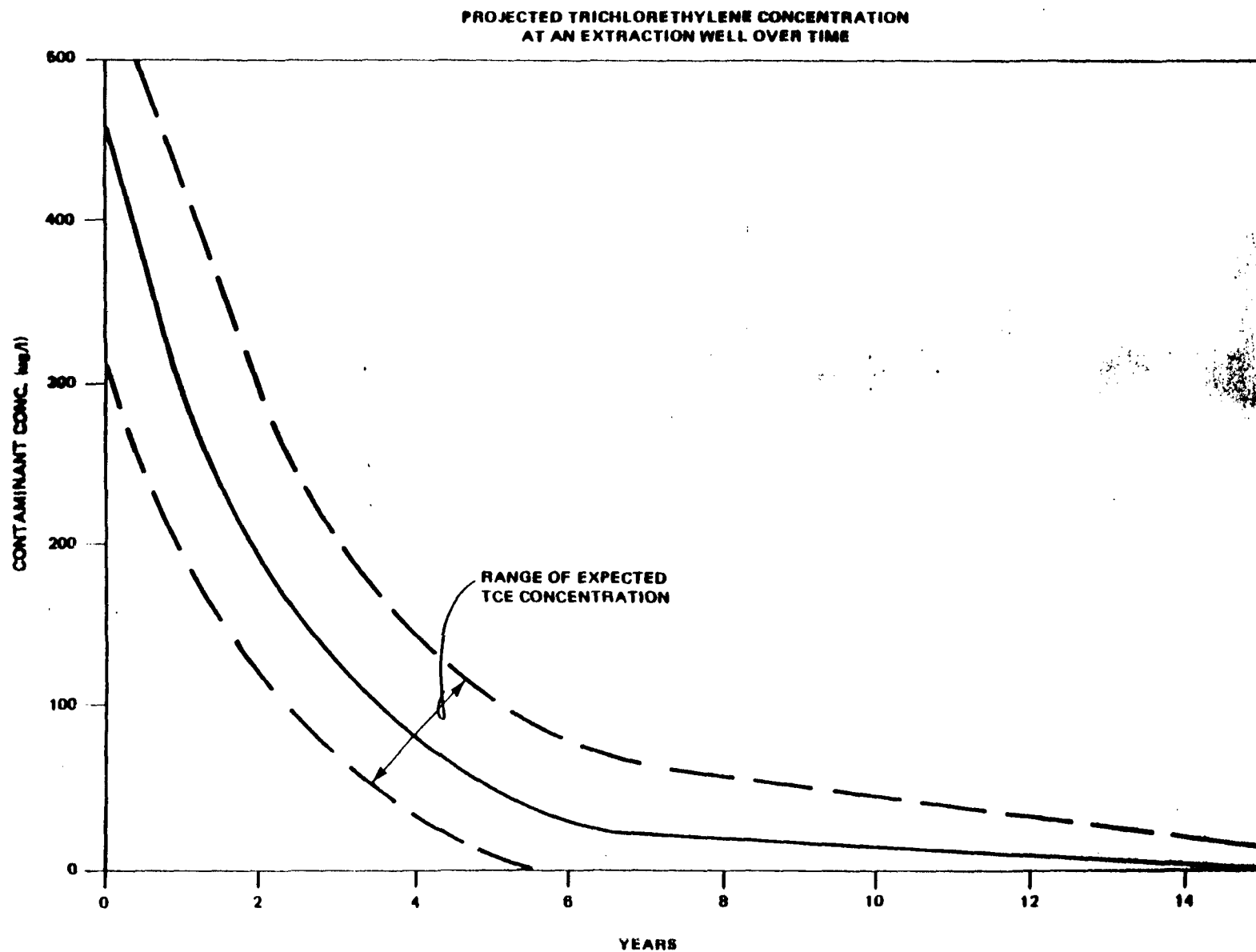
- o Ingestion of water during swimming
- o Dermal absorption during swimming
- o Ingestion of contaminated fish

Excess lifetime cancer risks for these pathways were calculated in a manner similar to that used in the endangerment assessment. The concentrations of TCE and PCE in the Lake Michigan discharge zone were estimated based on a conservative assumption of a 10 fold dilution. TCE and PCE concentrations in this zone would be equal to 10 percent of the levels shown in Figure 6-1 and 6-2. Excess lifetime cancer risks are shown in Table 6-2 for each of the pathways.

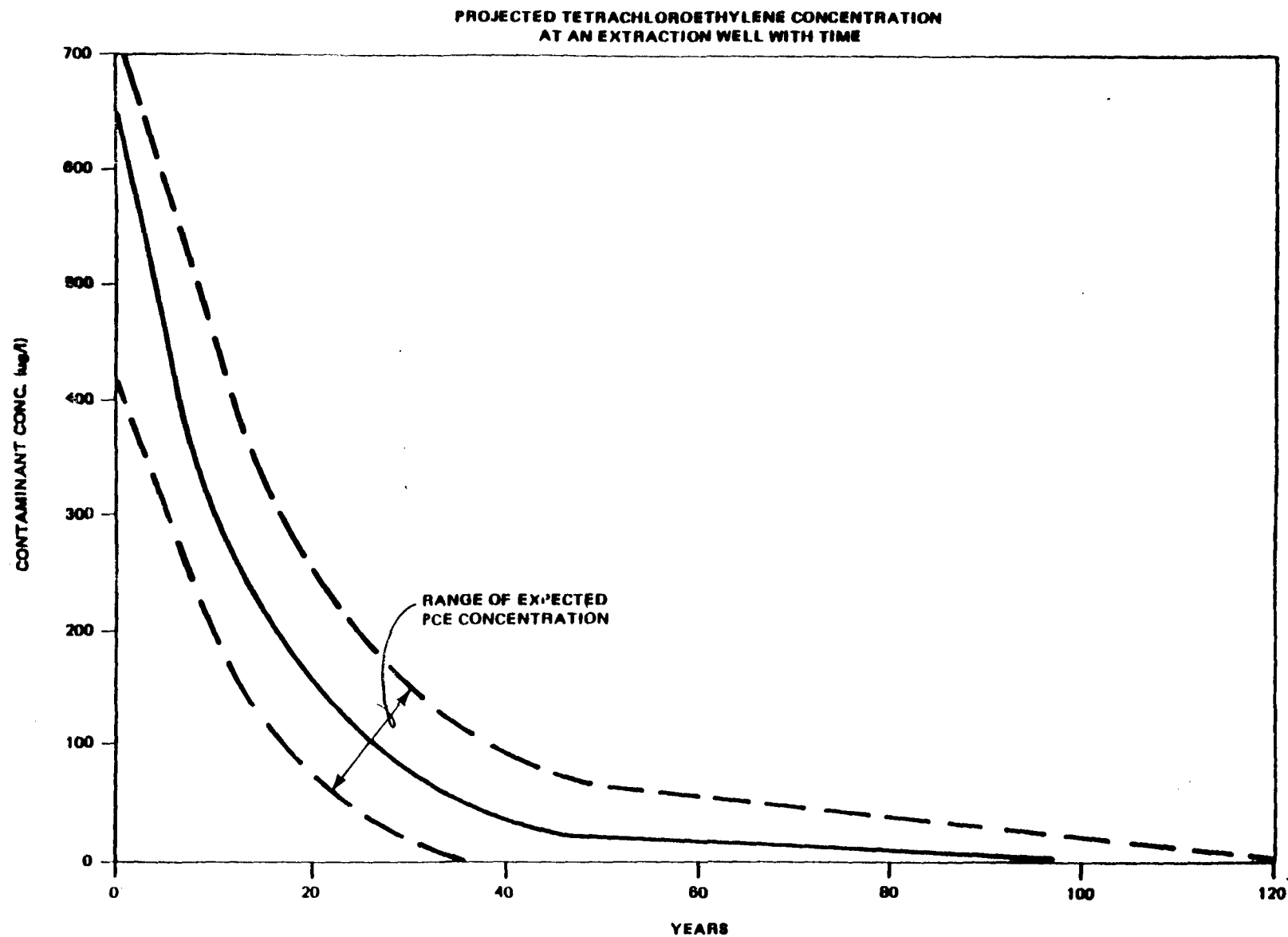
Overall, there is an increase in cancer risks for this alternative relative to the Limited Action alternative. The advantage of this alternative is it reduces by 20 years the time during which the illegal use of the contaminated groundwater would pose a health threat as compared to 50 years for the Limited Action alternative.

#### ENVIRONMENTAL ASSESSMENT

Exposure pathways for the biota are limited to the surface water. TCE and PCE concentrations in the Lake Michigan discharge zone during the first year of pumping, when levels would be highest, would be 40 ug/L and 60 ug/L, respectively (assuming a 10 fold dilution). EPA water quality criteria



**FIGURE 6-1  
TRICHLOROETHYLENE  
CONCENTRATION AT AN  
EXTRACTION WELL  
CHARLEVOIX SITE**



**FIGURE 6-2**  
**TETRACHLOROETHYLENE**  
**CONCENTRATION AT AN**  
**EXTRACTION WELL**  
CHARLEVILLE SITE



Table 6-2  
ALTERNATIVE B  
SUMMARY OF POTENTIAL FUTURE SURFACE WATER CONTAMINATION  
AND CANCER POTENCIES

<u>Compound</u>	<u>Cancer<sup>a</sup> Potency (mg/kg-day)<sup>-1</sup></u>	<u>Average Future Concentration (mg/L)</u>	<u>Lifetime Average Dose (mg/kg-day)</u>	<u>Excess Lifetime Cancer Risk</u>
<u>Water Ingestion During Swimming</u>				
Trichloroethylene	$1.9 \times 10^{-2} \text{ b}$	0.017	$1.7 \times 10^{-7}$	$3 \times 10^{-9}$
Tetrachloroethylene	$3.5 \times 10^{-2} \text{ b}$	0.131	$1.3 \times 10^{-6}$	$4 \times 10^{-8}$
<u>Dermal Absorption During Swimming</u>				
Trichloroethylene	$1.9 \times 10^{-2} \text{ b}$	0.017	$1.4 \times 10^{-5}$	$2 \times 10^{-7}$
Tetrachloroethylene	$3.5 \times 10^{-2} \text{ b}$	0.131	$1.0 \times 10^{-4}$	$4 \times 10^{-6}$
<u>Fish Consumption</u>		<u>mg/kg</u>		
Trichloroethylene	$1.9 \times 10^{-2} \text{ b}$	0.18	$1.2 \times 10^{-5}$	$2 \times 10^{-7}$
Tetrachloroethylene	$3.5 \times 10^{-2} \text{ b}$	4.0	$2.7 \times 10^{-4}$	$1 \times 10^{-5}$
TOTAL				$1 \times 10^{-5}$

<sup>a</sup>U.S. EPA 1984

<sup>b</sup>Although EPA gives potencies, the International Agency for Research on Cancer (IARC) ranks this compound as Group 3 - "The Chemical cannot be classified as to its carcinogenicity to humans."

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for acute toxicity are 45,000 ug/L for TCE and 5,280 ug/L for PCE, both substantially higher than the expected levels. The chronic toxicity criteria for PCE of 840 ug/L is also substantially higher than the 60 ug/L expected. As a result no significant impact on aquatic life is anticipated.

#### TECHNICAL EVALUATION

The Plume Extraction with Discharge to Lake Michigan alternative is technically straightforward. No problem would be anticipated in meeting the objective of the alternative. The reliability of the alternative would be very good since maintenance downtime for wells and pumps is usually a small percent of time. As a result, the alternative does not require backup extraction well pumps.

The extraction well installation could be implemented easily from a technical standpoint. Construction of the discharge piping would also be easy with the exception of the length necessary in Lake Michigan. This portion together with the end of pipe diffuser would likely require additional time to implement and necessitate contractor experience unavailable locally. Safety concerns for the alternative are not significant since the system is a well proven technology and will be totally enclosed, eliminating the potential for escape of volatile organics.

#### INSTITUTIONAL ISSUES

The main regulated activity of this alternatives is the discharge of untreated water to Lake Michigan. This would require a National Pollutant Discharge Elimination System (NPDES) permit issued by the MDNR establishing a maximum allowable concentration of PCE and TCE in the discharge. It is not clear at this time what limits would be required. This could be a major impediment to the viability of the alternative.

#### COST ANALYSIS

Costs for this alternative would be substantially higher than the Limited Action alternative it does decrease the number of years where a potential for incurring a threat to public health would exist, however, it also results in increased risk from discharge of untreated contaminated groundwater to Lake Michigan. It is questionable whether an NPDES permit would be issued by MDNR for the discharge at the estimated concentrations. For these reasons, the Plume Extraction with Discharge to Lake Michigan offers no advantage over the Limited Action alternative. As a result, detailed costing of this alternative was not performed.

## ALTERNATIVE C PLUME EXTRACTION WITH AIR STRIPPING TREATMENT

### DESCRIPTION

This alternative consists of plume extraction with two wells followed by treatment with air stripping. Plume extraction design and operation would be identical to that described under Alternative B.

The extracted groundwater would be piped to an air stripper to be located in the vicinity of the present municipal well in Charlevoix. A single tower would be required, 8 feet in diameter with two 20-foot sections of packed media in series and a maximum blower capacity of 5,000 cfm (Figure 6-3). Table 6-3 presents the design criteria for the air stripping tower.

The MDNR requires that vapor exhaust from an air stripping tower be scrubbed.

Treatment of the tower vapor exhaust for removal of volatile organics would be performed using a nonregenerable carbon adsorber system. The 5,000 cfm air stream would be heated before entry into the adsorber system and a vapor phase carbon would be used in the adsorbers. Table 6-4 presents carbon usage based upon predicted contaminant concentrations. A nonregenerable system has been selected because of the lower contaminant concentrations, the added complexity of a regenerable system, and relatively equal total costs.

Treated groundwater is anticipated to be discharged to Lake Michigan. Periodic laboratory analyses for monitoring operation of the system would be contracted because of the complexity and high initial cost of the required analytical equipment. Groundwater and surface water monitoring requirements would be similar to the Limited Action alternative as would land use and deed restrictions during the extraction period.

### PUBLIC HEALTH EVALUATION

Potential public exposure routes include groundwater, surface water and air pathways. Endangerment to public health via the groundwater exposure pathway is identical to Alternative B, since plume extraction will occur at the same rate. Potential surface water exposure pathways include:

- o Ingestion of water during swimming
- o Dermal absorption during swimming
- o Ingestion of contaminated fish

Excess lifetime cancer risks for these pathways are presented in Table 6-5. As with Alternative B, a conservative 10-fold

# CALCULATION OF AVERAGE VELOCITY OF CONTAMINANT MOVEMENT

$$v_c = \frac{v_i}{R_c}$$

where:

$v_c$  = average velocity of contaminant

$v_i$  = average velocity of groundwater

$R_c$  = retardation coefficient (d)

$$v_{c \text{ TCE}} = \frac{.8 \text{ ft/day}}{1.8654} = 0.4 \text{ ft/day}$$

$$v_{c \text{ PCE}} = \frac{.8 \text{ ft/day}}{4.3674} = 0.2 \text{ ft/day}$$

## GROUNDWATER PCE PLUME MASS FLUX TO LAKE MICHIGAN

$$\begin{aligned} M_P &= (Q_P)(C_P) = V_P(A_P)(C_P) \\ &= (0.2 \text{ ft}^3/\text{day})(.25 \text{ ft})(1,700 \text{ ft})(.25)(100 \text{ ug/L}) \\ &= (0.23 \times 10^6 \text{ ft}^3/\text{sec})(42,500 \text{ ft}^2)(2.8 \text{ mg/ft}^3) \\ &= (0.098 \text{ ft}^3/\text{sec})(2.8 \text{ mg/ft}^3) \\ &= 0.069 \text{ mg/sec} \end{aligned}$$

where:

$Q_P$  = total plume discharge  
 $V_P$  = specific plume discharge  
 $A_P$  = area  
 $C_P$  = PCE concentration  
 $M_P$  = mass flux due to groundwater plume

## CASE 1 - (HORIZONTAL PLUME DISCHARGE)

### LAKE MICHIGAN NEARSHORE ZONE MASS FLUX INTO MIXING ZONE

$$\begin{aligned} M_L &= (Q_L)(C_L) = (V_L)(A_L)(C_L) \\ &= (0.16 \text{ ft}^3/\text{sec})(6,250 \text{ ft}^2)(0 \text{ ug/L}) \\ &= (1,000 \text{ ft}^3/\text{sec})(0 \text{ ug/L}) \\ &= 0 \text{ mg/sec} \end{aligned}$$

where:

$Q_L$  = Lake Michigan inflow to mixing zone  
 $V_L$  = Lake Michigan mean monthly nearshore current velocity  
 $A_L$  = area  
 $C$  = PCE concentration in Lake Michigan inflow = 0 ug/L  
 $M_L$  = Mass flux due to Lake Michigan inflow

## Dilution Calculation

### Assuming Complete Mix and Steady State Conditions in Mixing Zone

$$M_F = M_P + M_L$$
$$(Q_F)(C_F)P = (Q_P)(C_P) + (Q_L)(C_L)$$

$$C_F = \frac{(Q_P)(C_P) + (Q_L)(C_L)}{Q_F}$$

$$= (0.069 \text{ mg/sec} + 0) / 1,000 / 3 \text{ ft}^3/\text{sec}$$
$$= 6.8 \times 10^{-3} \text{ gm/ft}^3$$
$$= 0.025 \text{ ug/L}$$

where:

$Q_F$  = final discharge from mixing area -  $Q_P + Q_L$   
 $C_F$  = final concentration of PCE in mixing zone  
 $M_F$  = final mass discharge from mixing zone

#### CASE 2 (300 FOOT DISCHARGE ZONE)

$$M_P = 0.069 \text{ mg/sec}$$
$$M_L = 0 \text{ mg/sec}$$
$$Q_L = (V_L)(A)$$
$$= (0.16 \text{ ft/sec})(1/2 [15 \text{ ft}] 300 \text{ ft})$$
$$= 360 \text{ ft}^3/\text{sec}$$
$$C_F = (M_P + M_L) / Q_F$$
$$= (0.069 \text{ mg/sec} + 0) / 360 \text{ ft}^3/\text{sec} + 0.025 \text{ ft}^3/\text{sec}$$
$$= 1.9 \times 10^{-4}$$
$$= 6.9 \times 10^{-3} \text{ ug/L}$$

#### CASE 3 (150 FOOT DISCHARGE ZONE)

$$M_P = 0.069 \text{ mg/sec}$$
$$M_L = 0 \text{ mg/sec}$$
$$Q_L = (V_L)(A)$$
$$= (0.16 \text{ ft/sec} [1/2 (7.5 \text{ ft}) (150 \text{ ft})])$$
$$= 0.90 \text{ ft}^3/\text{sec}$$
$$C_F = (M_P + M_L) / Q_F$$
$$= (0.069 \text{ mg/sec} + 0) / 90 \text{ ft}^3/\text{sec} = 0.025 \text{ ft}^3/\text{sec}$$
$$= 7.7 \times 10^{-4}$$
$$= 2.8 \times 10^{-3} \text{ ug/L} \longrightarrow .028 \text{ ug/L}$$

- (a) Freeze and Cherry (1979)
- (b) Distribution coefficient calculation from Karickhoff (1979)
- (c) Log Octanol/water partitioning coefficients taken from EPA Treatability Manual (1980).
- (d) Assumption: Remains constant during the period of interest.

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## Appendix B METHODOLOGY FOR THE ENDANGERMENT ASSESSMENT

This appendix presents the detailed methodologies used in the preliminary endangerment assessment to estimate human health risks caused by carcinogens.

### SUMMARY OF CHEMICAL PROPERTIES OF IDENTIFIED CONTAMINANTS

Compound: Trichloroethene

Synonyms:

Trichloroethylene; 1,1,2-trichloroethylene; TCE; 1,2,2,-trichloroethylene; 1-chloro-2,2-dichloroethylene; 1,1-dichloro-2-chloroethylene; ethynyl trichloride; trichloride; ethylene trichloride triclene, and various trade names.

CAS: 79-01-6

EPA HWM: U228

Sources:

Manufacture of organic chemicals and pharmaceuticals. Used in dry cleaning operations and metal degreasing; as solvent for fats, greases, waxes, cellulose ester and ethers, dyeing, for extraction of caffeine from coffee and in solvent extraction. A refrigerant and heat exchange liquid.

Environmental Fate

Volatilization appears to be the dominant transport process for removal of trichloroethene from aquatic environments (50% evaporation from water at 25°C after 19-24 min). Once the compound enters the atmosphere, it readily undergoes oxidation by hydroxyl radicals. There is some evidence of bioaccumulation of trichloroethene in marine organisms, but the process is probably not important relative to volatilization as a removal mechanism. There is, however, no evidence for biomagnification in aquatic food chains. In addition, no evidence has been found to suggest that adsorption to sediment is an important fate process.

Properties

Molecular Weight: 131.5  
Boiling Point: 86.7°C  
Vapor Pressure: 60 mm at 20°C  
Solubility: 1.100 mg/L at 25°C  
Flashpoint: None  
Bioconcentration Factor: 10.6

## Toxicity

Trichloroethene vapor is irritating to the eyes, nose and throat. The liquid is irritating to the skin and eyes. Trichloroethene is moderately toxic via inhalation and oral routes (ihl-hmn TCLo: 160 ppm/83 mm; orl-hmn LDLo: 857 mg/kg; orl-rat (LD50: 4920 mg/kg). Moderate exposure to the vapors can cause symptoms similar to alcohol inebriation. Inhalation of high concentrations causes narcosis and anesthesia. A form of addiction has been observed following prolonged exposure to the vapors. Acute exposure to trichloroethene may cause cardiac failure. Prolonged exposure results in damage to the liver and other organisms. Trichloroethene is metabolized and absorbed in the body.

Trichloroethene is toxic to aquatic organisms at high concentration (daphnia/TLm: 600 mg/L / 40 hr). The effect of low concentration on aquatic life is unknown.

## Carcinogenicity:

CAG potency:  $1.9 \times 10^{-2}$  (mg/kg/day)<sup>-1</sup>

IARC Group: 3

Limited animal evidence

Clean Water Act Water Criteria ( $10^{-6}$  excess cancer risk) for Human Health - Ingestion of:

Drinking Water Only: 2.8 ug/L

Fish and Drinking Water: 2.7 ug/L

Safe Drinking Water Act Health Advisories (mg/L)

1 day: 2

10 days: 0.2

## Exposures:

TLV-TWA: 50 ppm

TLV-STL: 200 ppm

OSH-TWA: 100 ppm

IDLH: 1,000 ppm

Compound: Tetrachloroethene

## Synonyms:

Tetrachloroethylene; perchloroethylene; PCE; PERC ethylene tetrachloride; carbon dichloride; carbon bichloride; and various trade names.

CAS: 127-18-4

Uses:

Dry cleaning and metal degreasing operations, manufacturing of fluorocarbons. Solvents for various organic substances.

Environmental Fate

Published studies indicate that volatilization followed by atmospheric reactions is the predominant fate for tetrachloroethene in the aquatic environment. Metabolization by higher organisms and bioaccumulation in marine organisms has been evidenced.

Properties

Molecular Weight: 165.83  
Boiling Point: 121.4°C  
Vapor Pressure: 14 mm at 20°C  
Specific Gravity: 1.624 at 20°C  
Solubility: 150 mg/L at 25°C  
Flashpoint: None  
Bioconcentration Factor: 10.7

Toxicity

Vapor is irritating to the eyes, nose, and throat. Low toxicity via ingestion (ori-rat LD50: 8.85 g/kg). Moderate toxicity via inhalation (inh-human TCLo: 96 ppm/7 hr). Affects liver, kidneys, eyes, upper respiratory system, and CNS.

The effect of low concentrations of tetrachloroethene on aquatic life is unknown.

Carcinogenicity

CAG Potency:  $3.5 \times 10^{-2}$  (mg/kg/day)<sup>-1</sup>  
IARC Group: 3  
Limited animal evidence

Clean Water Act Water Criteria ( $10^{-6}$  excess cancer risk) for Human Health Ingestion of:

Drinking Water Only - 0.88 ug/L  
Fish and Drinking Water - 0.8 ug/L

Safe Drinking Water Act Health Advisories (mg/L):

1 day: 2.3  
10 days: 0.18



### Exposures:

TLV-TWA: 50 ppm  
TLV-STEL: 200 ppm  
OSHA-TWA: 100 ppm  
IDLH: 500 ppm

### ESTIMATING HEALTH RISKS CAUSED BY CARCINOGENS

To estimate human health risks from carcinogens, the following information is used:

- o Lifetime average ingestion rates for water and fish
- o Lifetime average dermal absorption rates for bathing and swimming
- o Lifetime average chemical dose
- o Cancer potency
- o Chemical concentration

### ENDANGERMENT ASSESSMENT DISCUSSION OF UNCERTAINTY

The endangerment assessment for the area is based on the exposure to volatile organic compounds primarily through the ingestion or absorption of contaminated groundwater by residents.

The following assumptions are a conservative approach:

- o Chemicals are assumed not to degrade over time. The concentration does not vary due to plume movement. Dilution in the ground is not evaluated.
- o The sources of exposure quantified are from ingestion and dermal absorption.
- o The absorbed dose is 100 percent of the intake.

Users of the methodology described and the results obtained in this report should understand that it involves considerable uncertainty. The uncertainty is derived from numerous assumptions which may or may not accurately reflect actual conditions.

Factors leading to an overestimate of the health risks are:

- o Absorption was assumed to be 100 percent of dose from drinking water and dermal intake for the carcinogen.
- o The concentration of contaminants was held constant over a 70-year lifetime.

- o Clearance (excretion and exhalation) of contaminants is not considered in this analysis.
- o All of the daily water ingestion is through drinking groundwater.
- o All of the daily bathing is in water supplies from groundwater.

Factors leading to an underestimate of the health risk are:

- o The route of exposure via inhalation was not quantifiable.

Factors of uncertainty leading to either an overestimate or an underestimate of the health risks are:

- o The assumption regarding body weight, average life-time, population characteristics, and life style.
- o Skin absorption rates vary among individuals, and even for the same individual over time.
- o Hydration of the skin, amount of skin area exposed, solute temperature, skin condition, and physical/chemical properties of the compound of concern also affect absorption.
- o The groundwater use may vary over time, thereby varying the exposure to contaminants.
- o The carcinogenic potency used is subject to change as new evidence becomes available.
- o Risks may increase logarithmically instead of arithmetically with synergism or may decrease due to antagonistic action of other chemicals.
- o Substantial uncertainties are inherent in the estimation of risk. Uncertainties may act to increase or decrease risk, depending upon the source of uncertainty. Extrapolation of data from one species to another, from high dose to low dose, and from one exposure route to another introduce uncertainty.

#### DRINKING WATER INGESTION

##### Lifetime Average Drinking Water Ingestion Rates

The units on the cancer potency estimates from the Environmental Protection Agency's Carcinogen Assessment Group are (mg/kg body weight/day)<sup>1</sup>. The lifetime average chemical

intake must be estimated, therefore, in terms of mg/kg - body weight/day so that:

$$\text{Risk} = 1 - \exp (-[\text{potency} \times \text{dose}])$$

The lifetime average drinking water intake (LAWI, in L/kg body weight/day) for the residential scenario was estimated from:

$$\text{LAWI} = \frac{1}{N} \sum_{i=1}^N \frac{w_i}{b_i}$$

where

$N$  = number of years in a lifetime (70)  
 $b_i$  = body weight in year  $i$  (kg)  
 $w_i$  = drinking water intake in year  $i$  (l/day)

For a 70 year lifetime, LAWI was estimated as 0.035 l/kg/day based on the data in Table B-1. The derivation of this is demonstrated in Table B-2.

#### Lifetime Average Chemical Intake

The lifetime average chemical intake from water ingestion is the lifetime dose from water ingestion.

The lifetime average chemical intake from drinking water, LACIW, is:

$$\text{LAWI}_i = \text{LAWI} = 1 \times \frac{1}{M} \sum_{i=1}^N C_i \times n_i$$

where:

$M$  = days in a lifetime  
 $N$  = days exposed to contaminated drinking water source  
 $C_i$  = means chemical concentration of contaminant in time period  $i$   
 $n_i$  = number of days in time period  $i$

#### Risk Estimation

The excess lifetime cancer risk from water ingestion in the residential setting was based on:

$$\text{Risk} = 1 - \exp (-[\text{potency} \times \text{dose}])$$

Table B-1  
ESTIMATED WATER INGESTION  
BY BODY WEIGHT AND AGE

<u>Age (Years)</u>	<u>Body Weight (kg)</u>	<u>Estimated Ingested Drinking Water (L/day)</u>
0-0.75	5	1
0.75-1.5	8	1
1.5-3.5	12	1
3.5-5	15	1
5-18	38	1.4
<u>&gt;18</u>	70	2

<sup>a</sup>Kimbrough et. al., 1984

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**Table B-2 (Sheet 1 of 3)**  
**LIFETIME AVERAGE INTAKE DERIVATIONS**

**LIFETIME AVERAGE WATER INTAKE DERIVATION (LAWI)**

(365.25 days x 0.75 yr) x 1 L/day + 5 kg =	54.7875
(365.25 days x 0.75 yr) x 1 L/day + 9 kg =	34.242
(365.25 days x 2.0 yr) x 1 L/day + 12 kg =	60.875
(365.25 days x 1.5 yr) x 1 L/day + 15 kg =	36.525
(365.25 days x 13 yr) x 1.4 L/day + 38 kg =	174.935
(365.25 days x 52 yr) x 2 L/day + 70 kg =	<u>542.657</u>

904.022 L/kg/70 years  
12.915 L/kg/year  
0.0353 L/kg/day

**LIFETIME AVERAGE DAILY DERMAL INTAKE DERIVATION (LADDI) FROM BATHING**

Infant	3.5 yr x (0.001 L/cm <sup>2</sup> xhours) <sup>a</sup> x 65 hours <sup>b</sup> /yr x 80% immersed x 4,000 cm <sup>2</sup> <sup>a</sup> + 9.6 kg = 75.83 L/kg
Child	14.5 yr x (0.001 L/cm <sup>2</sup> x hours) <sup>a</sup> x 65 hours <sup>b</sup> /hr x 80% immersed x 8,800 cm <sup>2</sup> <sup>a</sup> + 35.6 kg = 186.38 L/kg
Adult	52 yr x (0.001 L/cm <sup>2</sup> x hours) <sup>a</sup> x 65 hours <sup>b</sup> /yr x 80% immersed x 18,000 cm <sup>2</sup> <sup>a</sup> + 70 kg = 695.31 L/kg

957.52 L/kg - 70 yr  
13.68 L/kg-yr  
0.037 L/kg-day

**Assumptions for LADDI for Bathing**

People bath 5 times per week<sup>b</sup>, 15 minutes each time and<sup>b</sup> are 80% immersed.

**LIFETIME AVERAGE DERMAL INTAKE DERIVATION (LADDI) FROM SWIMMING**

3.5 years x (0.001 L/cm <sup>2</sup> x hrs) <sup>a</sup> x 0 hrs/yr x 0% immersed x 4,000 cm <sup>2</sup> <sup>a</sup> + 9.6 kg = 0 L/kg
19.5 years x (0.001 L/cm <sup>2</sup> x hrs) <sup>a</sup> x 2.5 hrs/yr x 80% immersed x 8,800 cm <sup>2</sup> <sup>a</sup> + 35.6 kg = 8.1685 L/kg
52 years x (0.001 L/cm <sup>2</sup> x hrs) <sup>a</sup> x 1.25 hrs/yr x 80% immersed x 18,000 cm <sup>2</sup> <sup>a</sup> + 70 kg = 13.371 L/kg

21.54 L/kg 70 yr  
0.3077 L/kg yr  
0.0008 L/kg-day

Table 6-12  
REMEDIAL ACTION DETAILED ANALYSIS SUMMARY

Remedial Action	Public Health Evaluation	Environmental Assessment	Technical Evaluation	Institutional Issues	Costs		
					Capital Cost	GM Present Worth Cost	Total Present Worth Cost
Alternative A Limited Action	Cancer risk potential exists if inadvertent or intended illegal use of groundwater occurs for a period of 50 years during which the plume is naturally purged.	No significant impact on aquatic life.	Performance, reliability, implementability and safety are all rated very high.	EPA GWPS cleanup goal not met for 50 years. No plume cleanup may not meet Michigan groundwater quality requirements. Community not likely to be concerned since a new water supply is being built.	0	\$120,340	\$120,340
Alternative B Plume Extraction With Discharge to Lake Michigan	Period during which cancer risk potential exists for use of groundwater is reduced by 20 years from no action. Excess lifetime cancer risk for exposure to TCE and PCE in Lake Michigan is unacceptably high.	No significant impact on aquatic life.	Performance, reliability, and safety are rated high. Implementability may be slowed due to need for greater contractor expertise in construction of lake discharge pipe.	NPDES permit may not be issued for discharge of untreated contaminated groundwater. EPA GWPS cleanup goal not met for 50 years. Community acceptance may be negative due to discharge of contaminated groundwater to Lake Michigan.	Costs not calculated due to unacceptability of public health and institutional impacts.		
Alternative C Plume Extraction With Air Stripping Treatment	Period during which cancer risk potential exists for use of groundwater is reduced by 20 years from no action. Discharge of treated groundwater does not pose a threat to public health.	No significant impact on aquatic life.	Performance, reliability, and safety are rated high. Implementability may be slowed due to construction expertise needed for lake discharge pipe.	NPDES permit required, but likely issued for the effluent criteria of TCE = 2.8 ug/L and PCE = 0.8 ug/L. EPA GWPS cleanup goal not met for 50 years. Community acceptance likely positive.	\$1,631,000	\$3,120,900	\$4,757,900
Alternative D Plume Extraction With Carbon Adsorption Treatment	Period during which cancer risk potential exists for use of groundwater is reduced by 20 years from no action. Discharge of treated groundwater does not pose a threat to public health.	No significant impact on aquatic life.	Performance and safety are rated high. Reliability is good but less than air stripping due to carbon exhaustion and replacement requirements. Implementability may be slowed due to construction expertise needed for lake discharge pipe.	NPDES permit required, but likely issued for the effluent criteria of TCE = 2.8 ug/L and PCE = 0.8 ug/L. EPA GWPS cleanup goal not met for 50 years. Community acceptance likely positive.	\$2,093,000	\$2,300,000	\$4,401,000

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**APPENDIXES**

## Appendix A

### CALCULATION OF AVERAGE GROUNDWATER VELOCITY USING DARCY'S LAW

$$v_i = \frac{KI}{n}$$

where

K = hydraulic conductivity =  
300 gpd/ft<sup>2</sup> = 40.1 ft/day  
v<sub>i</sub> = average linear pore water  
velocity  
I = hydraulic gradient = 0.005 ft/  
ft  
n = effective porosity = 0.25

$$v_i = \frac{(40.1 \text{ ft/day}) (.005)}{0.25} = 0.8 \text{ ft/day}$$

### CALCULATION OF THE RETARDATION COEFFICIENT

$$R_c = \frac{v_i}{v_c} = 1 + \frac{P_b}{n} \cdot K_d$$

where:

R<sub>c</sub> = retardation coefficient  
v<sub>i</sub> = average linear velocity of the  
groundwater  
v<sub>c</sub> = velocity of the reactive contaminant.  
P<sub>b</sub> = bulk mass density = 1.8 g/cm<sup>3</sup> (a)  
n = porosity = .25  
K<sub>d</sub> = distribution coefficient in mL/g  
M<sup>d</sup> = 0.001 = 1/10 of 1% of organic  
matter

$$K_d = (M) (10)^{[\log K_{ow} - 0.21]} \quad (b)$$

where:

log K<sub>ow</sub> = log octonal/water  
partitioning coefficient (c)

TCE

$$\begin{aligned} \log K_{ow} &= 2.29 \\ K_{ow} &= 0.1202 \\ R_c &= 1.8654 \end{aligned}$$

PCE

$$\begin{aligned} \log K_{ow} &= 2.88 \\ K_{ow} &= 0.4677 \\ R_c &= 4.3674 \end{aligned}$$

**Table 6-6**  
**AIR STRIPPING ANNUAL OPERATION AND MAINTENANCE COSTS**

<u>Year</u>	<u>Annual Operating Cost (dollars)</u>	<u>Present Worth Cost (dollars)</u>
1	519,400	470,000
2	457,000	374,200
3	414,000	306,700
4	382,500	256,400
5	359,800	218,200
6	341,600	187,500
7	327,100	162,500
8	314,700	141,400
9	304,200	123,700
10	294,900	120,000
11	286,800	95,500
12	279,500	84,200
13	272,800	74,400
14	266,500	65,700
15	260,800	58,200
16	255,300	51,500
17	250,400	45,800
18	246,000	40,700
19	241,700	36,200
20	237,800	32,200
21	234,100	28,700
22	230,700	25,600
23	227,600	22,800
24	224,600	20,400
25	221,800	18,200
26	219,300	16,300
27	217,000	14,600
28	214,700	13,100
29	212,600	11,700
30	210,800	10,500

Total Present Worth Value:

\$3,126,900

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Table 6-7 (Page 1 of 2)  
AIR STRIPPING SYSTEM COST SUMMARY

	<u>30-year</u>
Stripping Tower	\$160,000
Tower	
Packing	
Blowers	
Mechanical	100,000
Pumps	
Piping	
Ductwork	
Electrical	82,000
Site Electrical	
Controls	
Instrumentation	
Telemetry	10,000
Emission Control Equipment	150,000
Carbon Adsorbers	
Fans, Ductwork, Piping	
Building	160,000
Structural	211,000
Pump Pit	
Steel	
Concrete	
Site Work	32,000
Access Roads	
Fencing	
Grading	
Landscaping	
Well Installations	186,000
SUBTOTAL:	1,091,000
Contingencies (30%)	327,000
SUBTOTAL:	1,418,000
Engineering, Legal & Administration Costs (15%)	213,000
SUBTOTAL:	\$1,631,000
GLT441/7-1	

Table B-2 (Sheet 2 of 3)

Assumptions for LADDI for Swimming

For swimming assume infants do not swim, children swim 10 times per year 15 minutes each time 80 percent immersed.

For swimming assume adults swim five times per year 15 minutes each time and 80 percent immersed.

LIFETIME AVERAGE WATER INTAKE DERIVATION (LAWI) DURING SWIMMING

$$(365.25 \text{ days} \times 0.75 \text{ yr}) \times 0 \text{ L/day} + 5 \text{ kg} = 0$$

$$(365.25 \text{ days} \times 0.75 \text{ yr}) \times 0 \text{ L/day} + 9 \text{ kg} = 0$$

$$(365.25 \text{ days} \times 2.0 \text{ yr}) \times 0 \text{ L/day} + 12 \text{ kg} = 0$$

$$(365.25 \text{ days} \times 1.5 \text{ yr}) \times 0.001 \text{ L/day} + 15 \text{ kg} = 0.0365$$

$$(365.25 \text{ days} \times 13 \text{ yr}) \times 0.001 \text{ L/day} + 38 \text{ kg} = 0.1249$$

$$(365.25 \text{ days} \times 52 \text{ yr}) \times 0.0007 \text{ L/day} + 70 \text{ kg} = \underline{0.1899}$$

$$0.3513 \text{ L/kg/70 years}$$

$$0.005 \text{ L/kg/year}$$

$$0.00001 \text{ L/kg/day}$$

Assumptions for LAWI From Swimming

Infants do not swim.

Children swim 10 times per year and ingest 50 ml<sup>C</sup> of water each swim.

Adults swim 5 times per year and ingest 50 ml<sup>C</sup> of water each swim.

FISH INGESTION

Lifetime Average Daily Fish Ingestion

$$365.25 \text{ days} \times 3.5 \text{ years} \times 0 \text{ gm of fish/day} + 9.6 \text{ kg body weight} = 0 \text{ gm of fish/kg body weight}$$

$$365.25 \text{ days} \times 14.5 \text{ years} \times 0 \text{ gm of fish/day} + 35.6 \text{ kg body weight} = 0 \text{ gm of fish/kg body weight}$$

$$365.25 \text{ days} \times 52 \text{ years} \times 6.5 \text{ gm of fish/day}^C + 70 \text{ kg body weight} = 1763.6357 \text{ gm of fish/kg body weight}$$

$$1763.6357 \text{ g of fish/kg} - 70 \text{ years}$$

$$25.1947 \text{ g of fish/kg} - \text{year}$$

$$0.069 \text{ g of fish/kg} - \text{day}$$

Table B-2 (Sheet 3 of 3)

Assumptions for Fish Ingestion

Only adults consume fish from the lake.

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<sup>a</sup> Brown et al, 1984

<sup>b</sup> Feinsilber & Meed, 1980

<sup>c</sup> ICF, Environ, 1983

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The excess lifetime cancer risk from residential water ingestion was estimated as:

$$R_i = 1 - \exp \{-[P_i \times C_i \times LAWI \times f]\}$$

where:

$$LACIW = C_i \times LAWI \times f$$

therefore:

$$R_i = 1 - \exp \{-[P_i \times LACIW_i]\}$$

where:

$R_i$  = lifetime excess risk from chemical i

$P_i$  = potency of carcinogen obtained from EPA's carcinogen assessment group (mg/kg-day<sup>-1</sup>)

$C_i$  = concentration of chemical i (mg/L)

$LAWI$  = lifetime average water intake (L/kg-day)

$f$  = fraction of lifetime that exposure occurs

#### Sample Calculation for Residential Water Ingestion

Example: The water supply from the well has trichloroethene in it at a concentration of 0.2 mg/L. The exposure takes place in the city. A 70 year lifetime is assumed.

- o Determine the lifetime average water ingestion rate (LAWI)

$$LAWI = 0.035 \text{ L/kg day based on Table B-2}$$

- o Determine the lifetime average chemical intake from the water ingestion (LACIW<sub>TCE</sub>)

$$LACIW_{TCE} = LAWI \times C_w$$

$$= 0.035 \text{ L/kg-day} \times 0.2 \text{ mg/L}$$

$$= 0.007 \frac{\text{mg}}{\text{kg-day}}$$

- o Determine the excess lifetime cancer risk

$$\text{Risk}_{TCE} = 1 - \exp \{-[\text{Potency} \times \text{Dose}]\}$$

$$\text{when dose} = LACIW_{TCE}$$



$$\text{Risk}_{\text{TCE}} = 1 - \exp \left( -[1.9 \times 10^{-2} (\text{mg/kg-day})^{-1} \right. \\ \left. (\text{reference 2}) \times 0.007 \text{ mg/kg-day}] \right)$$

$$\text{Risk}_{\text{TCE}} = 1.3 \times 10^{-4}$$

Or it may be expressed as  $130 \times 10^{-6}$   
i.e., 130 excess lifetime cancers per million  
people

To determine the risk associated with ingestion of water during swimming you can substitute the swimming ingestion rate of 0.00001 L/kg-day from Table B-2 for the drinking water ingestion rate and determine the average concentration of the contaminant in surface water and calculate it through in much the same manner as drinking water.

#### LIFETIME AVERAGE DERMAL INTAKE DURING BATHING

The units on the cancer potency estimates from the Environmental Protection Agency's Carcinogen Assessment Group are (mg/kg body weight/day). The lifetime average chemical intake must be estimated, therefore, in terms of mg/kg body weight/day so that:

$$\text{risk} = 1 - \exp \left( -[\text{potency} \times \text{dose}] \right).$$

The lifetime average daily dermal intake (LADDI, in liters/kg body weight/day) was estimated from:

$$\text{LADDI} = \frac{1}{M} \sum_{i=1}^N k \frac{a_i}{b_i} g_i \times C$$

where:

M	=	number of years in a lifetime (70)
$b_i$	=	body weight in year i (kg)
$a_i$	=	body surface area in year (cm <sup>2</sup> )
$g_i$	=	fraction of body surface area immersed
c	=	annual time spent bathing (hrs/yr)
K	=	permeability constant (liter/cm <sup>2</sup> . hr)
N	=	number of years exposed to contaminants in water

For a 70 year lifetime, the LADDI for bathing was estimated as 0.037 L/kg-body weight/day based on the data in Table B-2. The derivation of this is demonstrated in Table B-2.

### LIFETIME AVERAGE DERMAL DOSE FROM BATHING

The lifetime average daily dermal dose from dermal intake is the lifetime dose from dermal intake.

the Lifetime Average Daily Dermal Dose from water, LADDD, is:

$$LADD = LADDI \times \frac{1}{N} \sum_{i=1}^N C_i \times n_i$$

Where:

- M = days in a lifetime
- N = days exposed to contaminants in water
- C<sub>i</sub> = mean chemical concentration of contaminant in time period i
- n<sub>i</sub> = number of days in time period i

### Estimating Risks Associated with Dermal Absorption of Groundwater

The excess lifetime cancer risk from dermal intake was based on the following:

$$\text{Risk} = 1 - \exp(-[\text{dose} \times \text{potency}])$$

The excess lifetime cancer risk from water ingestion was estimated as:

$$R_i = 1 - \exp(-[P_i \times C_i \times LADDI])$$

but since:

$$LADDD_i = C_i \times LADDI$$

Risk can be expressed as:

$$R_i = 1 - \exp(-[P_i \times LADDD_i])$$

R<sub>i</sub> = Individual increased cancer risk over lifetime from chemical i

P<sub>i</sub> = Potency of carcinogen obtained from EPA's carcinogen assessment group (mg/kg-body weight/day)<sup>-1</sup>

C<sub>i</sub> = Concentration of chemical i (ug/L)

LADDI = Lifetime average daily dermal intake (L/kg-body weight/day)

### Sample Calculation for Dermal Intake

**Example:** Estimate the excess lifetime cancer risk for a 70 year lifetime from dermal intake of groundwater from the area due to trichloroethene, using a mean value of 0.002 mg/L.

1. Determine the lifetime average daily dermal intake rate (LADDI)

LADDI = 0.037 L/kg-body weight/day based on Table B-2

2. Determine the lifetime daily dermal dose from absorption (LADDD) of TCE

$$\begin{aligned} \text{LADDD}_{\text{tce}} &= \text{LADDI} \times C_{\text{tce}} \\ &= 0.037 \text{ L/kg-body weight/day} \times 0.002 \text{ mg/L} \\ &= 0.000074 \text{ mg/kg-body weight/day} \end{aligned}$$

3. Determine the excess lifetime cancer risk

Risk =  $1 - \exp(-[\text{Potency} \times \text{Dose}])$   
where dose = LADDD

$$\begin{aligned} \text{Risk}_{\text{tce}} &= 1 - \exp[-(P_{\text{tce}} \times \text{LADDD}_{\text{tce}})] \\ &= 1 - \exp[-(1.5 \times 10^{-2} \text{ (mg/kg-body weight/day)} \\ &\quad \times 0.000074 \text{ mg/kg-body weight/day})] \\ &= 1.4 \times 10^{-6} \\ &\quad \text{i.e., 1.4 excess cancers per million people} \end{aligned}$$

To determine the risk associated with dermal absorption of water during swimming you can substitute the dermal absorption rate of 0.0008 L/kg-day from Table B-2 for the dermal absorption rate for bathing and determine the average concentration of the contaminant in surface water and calculate it through in much the same manner as dermal absorption from bathing.

### FISH INGESTION

#### Lifetime Average Daily Fish Ingestion Rate

The units on the cancer potency estimates from the environmental Protection Agency's Carcinogen Assessment Group are (mg/kg body weight/day)<sup>-1</sup>. The lifetime chemical intake must be estimated, therefore, in terms of mg/kg-body weight/day, so that

Table 6-7 (Page 2 of 2)

	<u>30-year</u>
Annual Operating & Maintenance Costs (see Table 6-6)	-
Present Worth O&M Costs (10% Interest)	\$3,126,900
Total Present Worth Capital, O&M Costs (10% Interest)	\$4,757,900

Notes:

1. Power costs based on \$0.06 per kWh. Carbon based on \$1.00 per pound vapor phase carbon.
2. Plant staff assumed to be 1 superintendent, 1 operator, 1 part-time operator (for 4 months).
3. Annual O&M costs include 5 percent equipment replacement costs.

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$$\text{Risk} = 1 - \exp \{-[\text{potency} \times \text{dose}]\}$$

The lifetime average daily fish ingestion (LADFI, in mg/kg body weight/day) assuming only adults consume fish from the river, was estimated from:

$$\text{LADFI} = \frac{n}{N} \times \frac{f_i}{b_i}$$

where:

N = number of years in lifetime (70 years)  
 n = number of years fish from the river are consumed (52 years)  
 $f_i$  = daily fish ingestion (6.5 grams)  
 $b_i$  = body weight of adult (70 kg)

LADFI was estimated as 0.069 g/kg body weight/day. The derivation of this is shown in Table B-2.

#### Lifetime Average Chemical Intake

The lifetime average chemical intake from fish ingestion results in an average lifetime dose from fish consumption.

The lifetime average chemical intake from fish ingestion LACFI is:

$$\text{LACFI} = \text{LADFI} \times C_f = 0.069 \text{ g/kg-day} \times C_f$$

where:

$C_f$  = chemical concentration in fish fillets (edible portion)

#### Risk Estimation

The excess lifetime cancer risk from fish ingestion was calculated using:

$$\text{Risk} = 1 - \exp \{-[\text{potency} \times \text{dose}]\}$$

The excess lifetime cancer risk from fish ingestion was estimated as:

$$R_i = 1 - \exp (P_i \times C_i \times \text{LADFI})$$

where:

$$\text{LACFI}_i = C_i \times \text{LADFI}$$

therefore:

$$R_i = 1 - \exp \{-[P_i \times \text{LACFI}]\}$$

where:

- $R_1$  = lifetime excess risk from chemical  
 $P_1$  = potency of carcinogens obtained from EPA's carcinogen assessment group (mg/kg-day)<sup>-1</sup>  
 $C_1$  = concentration of chemical; in fish fillets in (mg/kg)  
 $LADFI$  = lifetime average fish ingestion (g/kg-day)

#### Sample Calculation for Fish Ingestion

Example: A fish fillet from the river contains 0.8 mg/kg ( $C_f$ ) Tetrachloroethene (PCE).

Sample number  
Table 3-2  
.0034 mg/kg

- o Determine the lifetime average daily fish ingestion rate (LADFI)

LADFI = 0.069 g/kg-day based on previous calculations

- o Determine the lifetime average chemical intake from the ingestion of fish ( $LACFI_{PCE}$ )

$$\begin{aligned} LACFI_{PCE} &= LADFI \times C_{PCE} \\ &= 0.069 \text{ g/kg-day} \times 0.8 \text{ mg/kg} \times 1 \text{ kg/1000g} \\ &= 0.000056 \text{ mg/kg-day} \end{aligned}$$

- o Determine the excess lifetime cancer risk

$$\text{Risk} = 1 - \exp(-[\text{Potency} \times \text{Dose}])$$

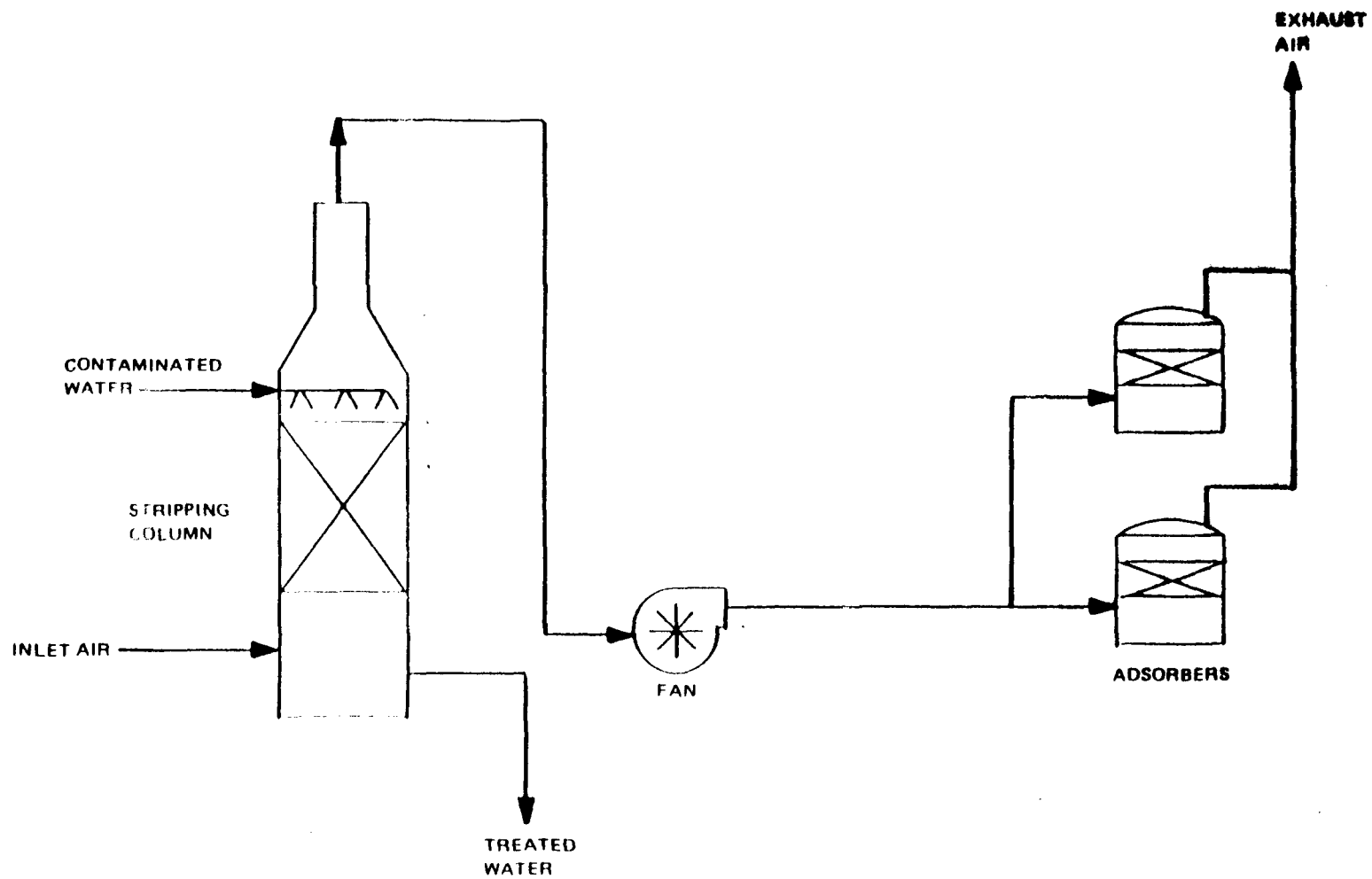
when dose =  $LACFI_{PCE}$

$$\text{Risk}_{PCE} = 1 - \exp(-[0.035 \text{ (mg/kg-day)}^{-1} \times 0.000056 \text{ mg/kg-day}])$$

$$\text{Risk}_{PCE} = 2.0 \times 10^{-6}$$

Or it may be expressed as  $2.0 \times 10^{-6}$ , i.e., 2 excess lifetime cancers per million people

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**FIGURE 6-3**  
**AIR STRIPPING PROCESS SCHEMATIC**  
**WITH NONREGENERABLE CARBON SYSTEM**  
CHARLEVOIX SITE

**Table 6-3**  
**AIR STRIPPING PROCESS DESIGN CRITERIA**

<b>Water Flow Rates</b>	
Pumping Rate	750 gpm
Air to Water Ratio	35:1
<b>Organics Removal</b>	
Trichloroethylene (TCE)	99.91%
Tetrachloroethylene (PCE)	99.9%
<b>Packing Depth</b>	
2 Beds @ 20 ft ht each	40 feet
Column Diameter	8 feet
Air Flow Rate	3,500 cfm

Predicted groundwater concentrations are shown in Figures 6-1 and 6-2.

**Effluent Concentration Goals**

TCE $10^{-6}$ cancer risk level	2.8 ppb
PCE $10^{-6}$ cancer risk level	0.8 ppb

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**TABLE 6-4**  
**PREDICTED ANNUAL CARBON USAGE**  
**AIR STRIPPING EMISSION CONTROL SYSTEM**

<u>Year</u>	<u>PCE (lb)</u>	<u>Carbon Usage (lb)</u>	<u>PCE (lb)</u>	<u>Carbon Usage (lb)</u>	<u>Total Annual Carbon Usage (lb)</u>
1	1,282	128,200	2,062	206,200	334,400
2	800	80,000	1,920	192,000	272,000
3	500	50,000	1,790	179,000	229,000
4	312	31,200	1,663	166,300	197,500
5	200	20,000	1,548	154,800	174,800
6	125	12,500	1,441	144,100	156,600
7	80	8,000	1,341	134,100	142,100
8	50	5,000	1,247	124,700	129,700
9	30	3,000	1,162	116,200	119,200
10	18	1,800	1,081	108,100	109,900
11	12	1,200	1,006	100,600	101,800
12	8	800	937	93,700	94,500
13	5	500	873	87,300	87,800
14	3	300	812	81,200	81,500
15	2	200	756	75,600	75,800
16	0	0	703	70,300	70,300
17	0	0	654	65,400	65,400
18	0	0	610	61,000	61,000
19	0	0	567	56,700	56,700
20	0	0	528	52,800	52,800
21	0	0	491	49,100	49,100
22	0	0	457	45,700	45,700
23	0	0	426	42,600	42,600
24	0	0	396	39,600	39,600
25	0	0	368	36,800	36,800
26	0	0	343	34,300	34,300
27	0	0	320	32,000	32,000
28	0	0	297	29,700	29,700
29	0	0	276	27,600	27,600
30	0	0	258	25,800	25,800

**Note:**

1. Based upon a total volume pumped each year of 394,200,000 gallons.
2. Based upon carbon usage of 100 lb carbon/lb contaminant removed.
3. Based upon predicted contaminant concentrations from Figures 6-1 and 6-2.

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Table 6-5  
ALTERNATIVES C AND D  
SUMMARY OF POTENTIAL FUTURE SURFACE WATER CONTAMINATION  
AND CANCER POTENCIES

<u>Compound</u>	<u>Cancer<sup>a</sup> Potency (ng/kg-day)<sup>-1</sup></u>	<u>Average Future Concentration (ng/L)</u>	<u>Lifetime Average Dose (ng/kg-day)</u>	<u>Excess Lifetime Cancer Risk</u>
<u>Water Ingestion During Swimming</u>				
Trichloroethylene	$1.9 \times 10^{-2} \text{ }^b$	0.00028	$3 \times 10^{-9}$	$5 \times 10^{-11}$
Tetrachloroethylene	$3.5 \times 10^{-2} \text{ }^b$	0.00008	$8 \times 10^{-10}$	$3 \times 10^{-11}$
<u>Dermal Absorption During Swimming</u>				
Trichloroethylene	$1.9 \times 10^{-2} \text{ }^b$	0.00028	$2 \times 10^{-7}$	$4 \times 10^{-9}$
Tetrachloroethylene	$3.5 \times 10^{-2} \text{ }^b$	0.00008	$6 \times 10^{-8}$	$2 \times 10^{-9}$
<u>Fish Consumption</u>				
		<u>mg/kg</u>		
Trichloroethylene	$1.9 \times 10^{-2} \text{ }^b$	0.003	$2 \times 10^{-7}$	$4 \times 10^{-9}$
Tetrachloroethylene	$3.5 \times 10^{-2} \text{ }^b$	0.002	$1 \times 10^{-7}$	$5 \times 10^{-9}$
TOTAL				$1.5 \times 10^{-8}$

<sup>a</sup>U.S. EPA 1984

<sup>b</sup>Although EPA gives potencies, the International Agency for Research on Cancer (IARC) ranks this compound as Group 3 - "The Chemical cannot be classified as to its carcinogenicity to humans."

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**Table 6-8**  
**CARBON ADSORPTION SYSTEM DESIGN CRITERIA**

Average Daily Flow Rate (AD)	750 gpm
No. of Columns	4
Diameter	12 feet
Overall Vessel Height	16 feet
Bed Depth @ 30 lb/cu ft	11.8 feet
(2) Parallel Streams	
(2) Columns in Series/Stream	
Contact time per stream @ AD	53 min
Contact time one stream only @ AD	27 min
Surface Loading Rate @ AD	3.32 gpm/ft <sup>2</sup>
Predicted groundwater concentrations of TCE and PCE taken from Figures 6-1 and 6-2, respectively.	
Effluent Concentration Goals	
TCE 10 <sup>-6</sup> cancer risk level	2.8 ppb
PCE 10 <sup>-6</sup> cancer risk level	0.8 ppb

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Table 6-9  
PREDICTED ANNUAL CARBON USAGE (CARBON ADSORPTION SYSTEM)

Year	PCE Concentration In Well (ppb)	Carbon Usage Rate (lb/1,000 gal)	Carbon Usage (lb/yr)	PCE Concentration In Well (ppb)	Carbon Usage Rate (lb/1,000 gal)	Carbon Usage (lb/yr)	Total Carbon Usage (lb/yr)
1	300	.22	88,000	605	.27	104,000	192,000
2	187	.17	68,000	563	.26	104,000	172,000
3	117	.13	52,000	524	.25	98,000	150,000
4	73	.10	40,000	488	.24	94,000	134,000
5	46	.08	31,000	454	.23	90,000	121,000
6	29	.06	24,000	423	.22	86,000	110,000
7	18	.05	19,000	393	.21	82,000	101,000
8	11	.04	14,000	366	.20	79,000	93,000
9	7	.03	11,000	341	.19	75,000	86,000
10	4	.02	8,000	317	.18	72,000	80,000
11	3	.02	7,000	295	.17	68,000	75,000
12	2	.01	6,000	275	.17	67,000	73,000
13	1	.01	4,000	256	.16	61,000	67,000
14	1	.01	4,000	238	.15	60,000	64,000
15	0	0	0	222	.15	56,000	58,000
16	0	0	0	206	.14	55,000	55,000
17	0	0	0	192	.13	53,000	53,000
18	0	0	0	179	.13	50,000	50,000
19	0	0	0	166	.12	48,000	48,000
20	0	0	0	155	.12	46,000	46,000
21	0	0	0	144	.11	44,000	44,000
22	0	0	0	134	.11	42,000	42,000
23	0	0	0	125	.10	40,000	40,000
24	0	0	0	116	.10	38,000	38,000
25	0	0	0	108	.09	37,000	37,000
26	0	0	0	101	.09	35,000	35,000
27	0	0	0	94	.09	34,000	34,000
28	0	0	0	87	.08	32,000	32,000
29	0	0	0	81	.08	31,000	31,000
30	0	0	0	76	.07	30,000	30,000

Note:

Based on a total volume of 394,200,000 gallons pumped each year.

Carbon usage rates are based upon carbon adsorption isotherms for toxic organics by Dobbs and Cohen (1980) times 1.5 for field performance.

Contaminant concentrations based upon predicted values from Figure 6-1 and 6-2.

dilution was assumed in the discharge area in Lake Michigan. TCE and PCE concentrations would be 0.28 ug/L and 0.08 ug/L, respectively.

Based on the cancer risks, the potential for carcinogenicity in humans from the surface water pathways is remote. The air exposure pathway in this alternative is eliminated by incorporating carbon treatment of the vapor exhaust. This will effectively eliminate risks from this exposure pathway.

#### ENVIRONMENTAL ASSESSMENT

Surface water is the only potential exposure pathway for the biota. TCE and PCE concentrations in the discharge zone in Lake Michigan would be 0.28 ug/L and 0.08 ug/L, respectively. These are five orders-of-magnitude less than EPA water quality criteria for acute toxicity for freshwater aquatic life. The PCE concentration is four orders-of-magnitude less than the chronic toxicity criteria for PCE. As a result, no impact on aquatic life is expected from discharge of the treated groundwater.

#### TECHNICAL EVALUATION

Since plume extraction and discharge facilities are identical to Alternative B, the technical assessment of that portion of the alternative applies to this alternative also.

Air stripping performance has proven to be effective in numerous applications for reducing VOC's to low levels. It is anticipated that the effluent criteria of 2.8 ug/L for TCE and 0.8 ug/L for PCE will be consistently met by this technology. Operation and maintenance requirements are greater than the previous alternatives but are relatively low for treatment technologies. Performance monitoring would be necessary at regular intervals and would be subcontracted to an analytical laboratory. Installation of the air stripping treatment system is not complex and is expected to proceed with a minimum of delays. Design, construction, and startup is estimated to take 1 year. Operator and nearby residents safety during operation is not considered to be a problem.

#### INSTITUTIONAL ISSUES

No significant negative institutional issues are anticipated for this alternative because contaminated groundwater would be extracted and treated prior to discharge to Lake Michigan. An NPDES permit would be required but would likely be issued by MDNR at the effluent limits discussed earlier.

Community acceptance would likely be positive since groundwater is being treated prior to discharge.

## COST ANALYSIS

Table 6-6 presents the annual operation and maintenance costs including carbon usage, power consumption, personnel costs, 5 percent equipment replacement costs, and laboratory analyses. Table 6-7 presents the air stripping system cost summary including present worth costs on a 30-year basis.

### ALTERNATIVE D PLUME EXTRACTION WITH CARBON ADSORPTION TREATMENT

#### DESCRIPTION

This alternative consists of plume extraction with two wells followed by treatment with carbon adsorption. Plume extraction design and operation would be identical to that described under Alternative B.

The extracted groundwater would be piped to a carbon adsorption system to be located in the vicinity of the present municipal well in Charlevoix. The carbon system (Figure 6-4) would consist of four carbon contact pressure tanks arranged in two parallel flow streams. The arrangement would provide two columns in series for each flow stream permitting the lead column to operate to exhaustion, therefore optimizing carbon usage. The columns would be valved and piped so that either column could be operated in the lead position. Each column would be 12 feet in diameter, 16 feet high, with a carbon bed depth of 11 to 12 feet. Table 6-8 presents the carbon adsorption system design criteria and Table 6-9 presents the predicted annual carbon consumption.

Each carbon column would hold two semi-truck loads of carbon (each truckload consists of 20,000 lbs, 667 cu ft at 30 lb/cu/ft carbon). A carbon transfer tank would be needed to transfer the spent carbon to, prior to refilling the adsorption columns. The delivery trucks could unload carbon into the empty adsorber column and then load spent carbon from the transfer tank for their return trip. Predicted average carbon usage indicates replacement of one column of spent carbon every 4 to 5 months. Telephone quotations received from carbon vendors indicate that the cost of regenerated carbon would be approximately the same as replacement with virgin carbon. For this analysis, replacement with virgin carbon is assumed. Virgin carbon costs are estimated at \$1.00 per pound.

Backwash of the carbon columns would be accomplished using a flow control valve off the finished water discharge pipe-line. Backwash at 15 gpm/ft would require a flow rate of 1,700 gpm at 22 psi. The backwash waste stream would be piped to the sanitary sewer.

Treated groundwater is anticipated to be discharged to Lake Michigan. Periodic laboratory analyses for monitoring oper-

ation of the system could be contracted because of the complexity and high initial cost of analytical equipment. Groundwater monitoring requirements would be similar to the Limited Action alternative as would land use and deed restrictions during plume extraction.

#### PUBLIC HEALTH EVALUATION

Potential public exposure routes include groundwater and surface water pathways. Public health risks would be identical to those described for Alternative C since plume extraction facilities and effluent discharge concentrations for the two alternatives are the same.

#### ENVIRONMENTAL ASSESSMENT

The only potential exposure pathway for the biota is the surface water pathway. Since effluent TCE and PCE concentrations will be the same as Alternative C, this alternative also is not expected to have impacts on aquatic life.

#### TECHNICAL EVALUATION

The technical evaluation of plume extraction facilities also applies to this alternative since the design and operation will be the same. Carbon adsorption treatment is effective and durable for reducing VOC's to low levels. Carbon adsorption achieves a high level of contaminant removal and it is anticipated that the effluent criteria for TCE and PCE will be consistently met. The process layout provides backup protection from contaminant breakthrough by using a series column arrangement.

Operation requires a higher level of mechanical attention because of carbon regeneration or replacement. Further, operation requires more frequent performance monitoring to track contaminant breakthrough and periodic carbon exhaustion. Installation difficulty is greater than air stripping due to the increased piping and valve requirements. Design, construction, and startup is estimated to take 1 year. Performance sample analysis would be subcontracted to an analytical laboratory. Safety is not considered to be a problem for treatment operators or nearby residents.

#### INSTITUTIONAL ISSUES

No significant negative institutional issues are anticipated for this alternative. An NPDES permit will be required and will likely be issued by MDNR for the TCE and PCE effluent limits discussed earlier.

Community acceptance is expected to be positive due to the treatment of the discharge.

## COST ANALYSIS

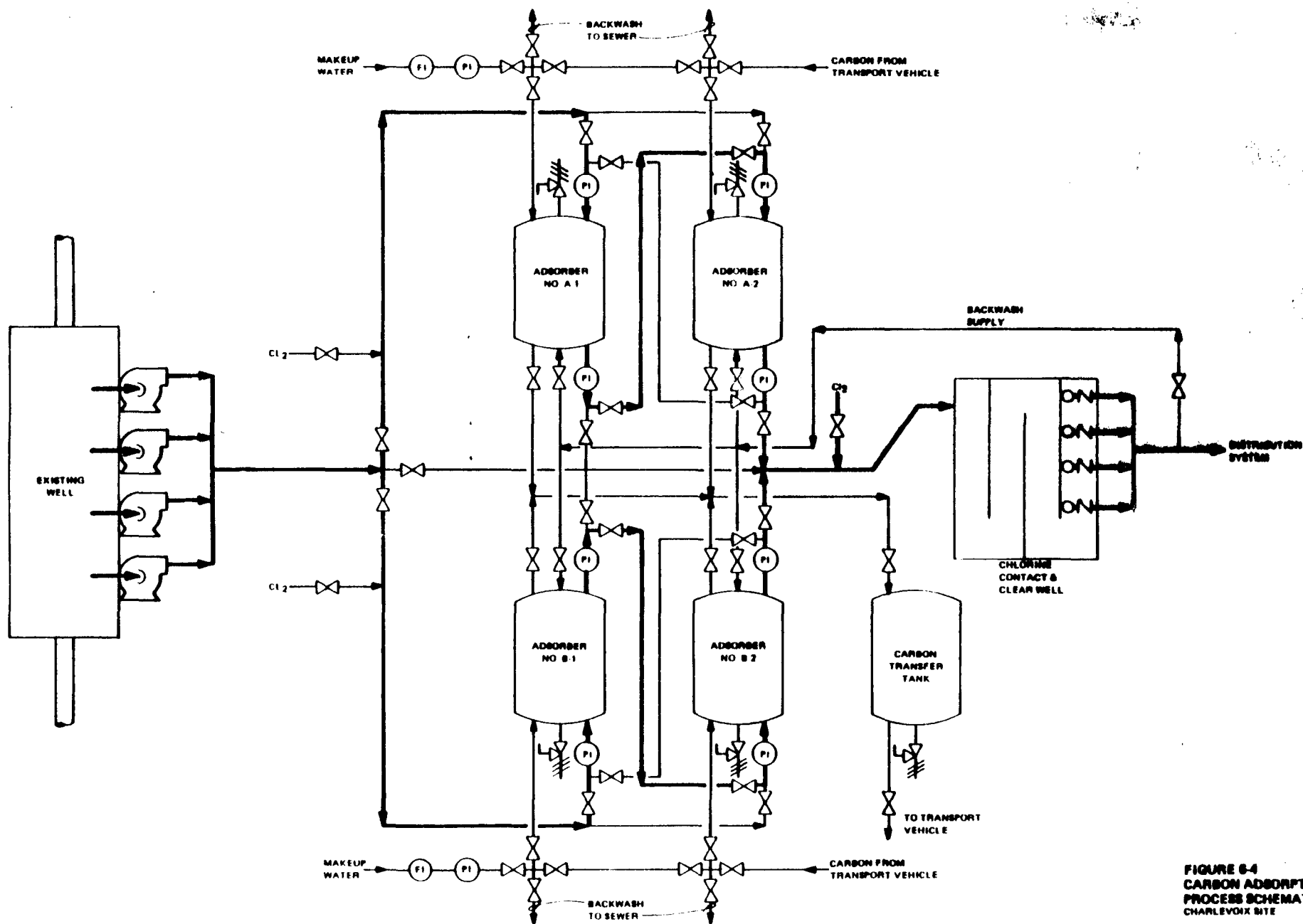
The majority of costs are associated with operation and maintenance of the activated carbon adsorption treatment system. Table 6-10 presents annual operation and maintenance costs based upon predicted carbon usage, pumping costs, additional personnel needs, 5 percent equipment replacement costs, and analysis costs. The relatively high operation and maintenance costs are primarily associated with replacement and regeneration of carbon in combination with extraction well maintenance. Table 6-11 presents a system cost summary including present worth values for a 30-year basis.

## SUMMARY

Table 6-12 provides a summary of the remedial action alternatives. Alternative B is the only alternative that significantly increases the health risks, Alternative C and D reduce the time to clean-up the aquifer but at a substantially increased cost. Alternative A has a significantly reduced cost but an extended time to clean-up the aquifer.

GLT441/2





**FIGURE 6-4**  
**CARBON ADSORPTION SYSTEM**  
**PROCESS SCHEMATIC**  
**CHARLEVOIX SITE**